The Flight Deck Perspective of the NASA Langley AILS Concept

NASA AILS Team Report

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Preface

This document presents the flight deck perspective component of the Airborne Information for Lateral Spacing (AILS) approaches to close parallel runways in Instrument Meteorological Conditions (IMC). It represents the ideas the NASA Langley Research Center (LaRC) AILS Development Team envisions to integrate a number of components and procedures into a workable system for conducting close parallel runway approaches.

An initial documentation of the aspects of this concept was sponsored by LaRC and completed in 1996 (Reference 1). Since that time a number of the aspects have evolved to a more mature state. This paper is an update of the earlier documentation.

A counterpart of this document has been written that describes and analyzes the AILS concept from an ATC system perspective (Reference 2, ATC ad hoc team).

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In conjunction with the development of the AILS process, the NASA LaRC development team has formed a partnership with a team from Honeywell Corp., Honeywell Technical Center, lead by Dr. William Corwin. The intent of the partnership is to demonstrate the concept in flight in 1999. Honeywell has evolved its variation of the concept under the name CASPER (Closely Spaced Parallel Approaches).

Executive Summary

The AILS concept can be thought of as partitioning the problem of instrument approaches to close parallel runways into two parts and incorporating procedures and technology to manage each. The two parts are: (1) to provide accurate flight path management and (2) address procedures to avoid potential collisions in the event an aircraft strays from its airspace.

Major aspects of this concept are to provide accurate flight path management to keep aircraft in their own assigned airspace along the approach paths and keep aircraft from threatening others. LaRC researchers are investigating whether the conventional localizer path can be replaced with capabilities such as the Differential Global Positioning System (DGPS) to provide parallel approaches where there is less potential for path overlap. An approach that is currently being explored is the use of offset, ILS-type approaches. The advantage of this latter approach is that there is an industry move toward the use of this lateral path guidance scheme “for GPS landing systems”. It is obvious that the better that the AILS concept integrates with current and other evolving systems, the greater the economic viability of such a concept. An alerting feature has also been incorporated in the concept to aid in preventing aircraft from straying from their airspace.

The second aspect of the LaRC AILS concept addresses procedures to avoid potential collisions in the event one aircraft strays from its airspace and approaches the path of another in a threatening manner. An onboard alerting algorithm will use state information from traffic on the close parallel runway, transmitted by the Automatic Dependent Surveillance-Broadcast (ADS-B) datalink, to detect threatening aircraft and provide an onboard alert to the flight deck crew. The alert is presented on the primary flight display (PFD) and the navigation display (ND). Alerting from this system could require the flight deck crew to perform an emergency escape maneuver (EEM) to avoid the threatening aircraft.

Once the EEM has been completed, it is envisioned that ATC will, through appropriate procedures, resume total responsibility for separating the airplanes involved in the incident from each other and other traffic. It is further assumed that the deviating aircraft will be issued instructions to guide them back into the approach sequence.

1.0 Glossary of Terms and Abbreviations

ADS-B	Automatic Dependent Surveillance – Broadcast
AILS	Airborne Information for Lateral Spacing
A/P	Autopilot
ARC	NASA Ames Research Center
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
ATIS	Automatic Terminal Information Service
Breakout	A technique to direct aircraft out of the approach stream. In the context of the close parallel approaches, it is used to direct threatened aircraft away from a deviating aircraft.
C	Captain
CASPER	Closely Spaced Parallel Approaches
Close Parallel Runways	Two parallel runways whose centerlines are separated by less than 4300 feet.
DGPS	Differential Global Positioning System
EADI	Electronic Attitude Director Indicator
ED	Enhanced Display
EEM	Emergency Escape Maneuver
EFIS	Electronic Flight Instrumentation System
EICAS	Engine Indication and Crew Alerting System
FAA	Federal Aviation Administration
FAF	Final Approach Fix
F/D	Flight Director
FMC	Flight Management Computer
FMS	Flight Management System
F/O	First Officer
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
Handoff	An action taken to transfer the radar identification of an aircraft from one controller to another if the aircraft will enter the receiving controller's airspace.
IFD	Integrated Flight Deck
IFR	Instrument Flight Rules
ILS	Instrument Landing System

ILS PRM Approach	An Instrument Landing System approach conducted to parallel runways whose extended centerlines are separated by less than 4300 ft. The parallel runways have a Precision Runway Monitor system that permits simultaneous independent ILS approaches.
IMC	Instrument Meteorological Conditions
LaRC	NASA Langley Research Center
LDA	Localizer-type Directional Aid
MAP	Missed Approach Point
MCD	Modified Conventional Display
Missed Approach	A maneuver conducted by a pilot when an instrument approach cannot be completed to a landing.
NAS	National Airspace System
MSP	Minneapolis-St. Paul International Airport
NASA	National Aeronautics and Space Administration
ND	Navigation Display
NM	Nautical Mile
NMAC	Near Mid-Air Collision
NTZ	No Transgression Zone
PF	Pilot Flying
PFD	Primary Flight Display
PNF	Pilot Not Flying
RNP	Required Navigation Performance
RTO	Rejected TakeOff
RWY	Runway
SAE	Society of Automotive Engineers, International
SFO	San Francisco International Airport
SEA	Seattle International Airport
SSR	Secondary Surveillance Radar
STL	St. Louis/Lambert International Airport
TCAS	Traffic Alert and Collision Avoidance System
VFR	Visual Flight Rules

Visual Approach	An approach conducted on an instrument flight rules (IFR) flight plan that authorizes the pilot to proceed visually and clear of clouds to the airport. The pilot must, at all times, have either the airport or the preceding aircraft in sight. This approach must be authorized and under the control of the appropriate air traffic control facility. Reported weather at the airport must be ceiling at or above 1000 ft. and visibility of 3 miles or greater.
Visual Separation	A means employed by ATC to separate aircraft in terminal areas and en route airspace in the National Airspace System (NAS). There are two ways to effect this separation: a. The tower controller sees the aircraft involved and issues instructions, as necessary, to ensure that the aircraft avoid each other. b. A pilot sees the other aircraft involved and upon instructions from the controller provides his own separation by maneuvering his aircraft as necessary to avoid it. This may involve following another or keeping it in sight until it is no longer a factor.
VMC	Visual Meteorological Conditions - Meteorological conditions expressed in terms of visibility, distance from clouds, and ceiling equal to or better than specified minima.
VREF	Speed Reference. The actual number is the basic, uncorrected approach speed with landing flaps.

2.0 Introduction

Many U.S. airports depend on parallel runway operations to meet the growing demand for day to day operations. In the current airspace system, IMC reduces the capacity of close parallel runway operations; that is, runways spaced closer than 4300 feet. These capacity losses can result in landing delays causing inconveniences to the traveling public, interruptions in commerce, and increased operating cost to the airlines.

In the AILS program, LaRC has developed a concept for conducting approaches to runways spaced closer than 4300 ft. that is based on flight deck centered technology.

Prior to the AILS research, the Federal Aviation Administration (FAA) had made progress on the problem of reduced capacity for close parallel runways in IMC in its Precision Runway Monitor (PRM) Program (Reference 3). Using ground based technology consisting primarily of high update rate, more accurate radar, and higher resolution displays for Air Traffic Control (ATC) controller stations, PRM has certified capabilities to operate independent parallel approaches as close as 3400 ft. in IMC.

The AILS concept has been formulated to enable operations to runways spaced closer than 3400 feet. There are two aspects of the AILS concept: accurate flight path management and providing monitoring, alerts and procedures in the event of an intrusion.

DGPS provides the basis for the accurate navigation required to perform the approach, while ADS-B will enable aircraft to broadcast their position and other state information such as track and rate of turn. All aircraft on AILS approaches will receive the transmitted information, allowing an accurate fix on other aircraft operating on a parallel approach. In addition, the transmitted state information will provide an indication of whether the traffic is properly maintaining its nominal path.

The purpose of this document is to present a system description of the AILS concept, focusing on the flight deck perspective. Reference 2 provides a description of the AILS concept from the ATC perspective. It is intended that this document together with Reference 2 would provide a complete description of the AILS process from the entire ATC/airborne systems perspective.

3.0 Scope of Report

The intent of this report is to provide an outline of NASA's program to reduce lateral separation during approach and landing between aircraft in IMC. Where appropriate, this report references other activities in support of AILS.

4.0 Concept Description

Independent straight-in approaches in all weather conditions are the baseline for AILS approaches. AILS approaches are somewhat similar to visual approaches in that the controller has transferred responsibility for lateral separation to the flight deck crew. The assumption is that onboard AILS equipment will support the flight deck crew in maintaining separation from traffic on the parallel approach and that the Traffic Alert and

Collision Avoidance System (TCAS) will assist in maintaining separation from other traffic operating in the area. The assumed airborne equipment includes an accurate flight path tracking capability based on technology such as DGPS and data communication between aircraft such as with ADS-B. It also includes an alerting system that will warn of an ownship deviating from its assigned airspace and of parallel traffic deviating from its airspace in a manner that may present a collision threat. A display of proximate traffic may be incorporated in the airborne system. Also, procedures for taking evasive action in the event of intrusions are clearly defined. Conventional TCAS will continue to operate and protect against intrusions from other traffic not monitored by the AILS system. However, this does not preclude an implementation where the AILS system may be incorporated in an expanded version of TCAS, a possibility which is under study.

The AILS concept assumes that Air Traffic Control (ATC) will establish each aircraft onto its final approach course before lateral separation responsibility is transferred to the aircraft. Prior to this, a vertical separation, nominally 1000 ft., will be maintained between the parallel traffic. Throughout this procedure, ATC retains longitudinal separation responsibility between aircraft in both parallel approach streams and separation from other aircraft not on final approach to the parallel runways. The AILS-equipped aircraft (with a qualified flight crew) accepts and retains lateral separation responsibility until landing. In the event that one aircraft blunders from its assigned approach course during the approach, the AILS algorithms will provide an alert for the blundering aircraft to return to its approach course. If the blundering aircraft fails to respond and threatens an aircraft in the parallel stream, the threatened aircraft is provided alerting for the potential collision situation. In this event, the threatened aircraft will perform a proceduralized emergency escape maneuver, which would have been briefed as part of the crew's approach briefing.

5.0 Background

The basic AILS concept involves a pair of close parallel runway approaches since this geometry represents a costly real world problem. Figure 1 shows two airplanes on close parallel runway approaches in IMC. Each aircraft is equipped with an accurate navigation system such as DGPS, an ADS-B communication link to transmit or broadcast its own state and other information for use by other airplanes, and ground facilities. Each airplane also receives the ADS-B information from the other airplanes operating within its proximity. The airplanes are equipped with a traffic display, possibly similar to the TCAS displays currently in use, and monitoring and warnings specific to the close parallel runway concept requirements. In this concept, the primary responsibility for maintaining separation from traffic operating on the close parallel runway approach is delegated by ATC to the flight deck. From a separation responsibility standpoint, this operation is similar to ATC oversight with current visual approaches to close parallel runways. However, separation responsibility from other traffic, such as that behind and ahead operating in the same approach stream, may be maintained as the responsibility of the ground based ATC operation.

The basic concept for conducting close parallel approaches in IMC can be partitioned into two primary aspects. The first is accurate navigation required to keep each aircraft on course. The second is an alerting system and escape procedure to insure safety in the event of an intrusion where one airplane leaves its nominal approach course and threatens the safety of an airplane on the adjacent parallel approach course. As a guideline, it was concluded that the display concepts should adhere as closely as reasonable to TCAS formats with deviations only where they appear to provide added value in supporting the parallel approach requirements. Furthermore, it was concluded that, in initial experimental implementations of the concept, the flight deck display of information should be presented as modifications to the PFD and ND since these are the display devices which normally occupy the majority of the pilots' attention during the approach phase of flight. Figures 2a,b show the nominal versions of these instruments as they appear in the NASA Transport Systems Research Vehicle (TSRV) Simulator used in previous AILS studies, with major display information labeled.

This concept requires accurate position sensing such as is available with DGPS to support accurate path tracking performance, which is the primary factor for operational safety in this concept. The DGPS capability is assumed to provide the accurate navigation to support the lateral path navigation along the entire approach. A conventional localizer profile is assumed (use of the conventional ILS localizer signal itself is neither required nor desirable under this concept). It is also recognized that other technology may well be capable of providing the required level of navigation accuracy.

LaRC is currently exploring the use of offset, ILS-type approaches. Using this technique, one or both of the localizers will be skewed away from the adjacent parallel runway so the localizer paths do not overlap. Considering the impact to current airport approach designs, one proposed plan would be to apply the necessary offset to the secondary runway of a runway pair while having no offset for the primary runway. In this regard, the necessary offset would be that angle that would assure no overlap of the approach boundaries. This secondary runway, lateral approach path could be designed similar to current LDA standards.

6.0 Alerting Functions

As previously stated, the AILS concept can be partitioned into two primary aspects. The first is flight path management, where accurate navigation is required to keep each aircraft on its respective course. The second is alerting for an intrusion, where alerts are generated for situations where the parallel traffic strays from its course and approaches the path of the ownship in a threatening manner. The AILS alerting algorithms are activated at the point at which the airplanes are aligned on the final approach course, approximately 10 NM from the runway threshold. Specific details for the alerting functions are provided later in the document.

The concept for presenting alerts in the flight deck was intended to adhere to the requirements of SAE ARP-4102/4 (Reference 4) and its recommendations for caution and warning alerting.

6.1 Flight Path Management

The first of the two alerting aspects of AILS deals with preventing aircraft from straying from their assigned airspace. This aspect itself is further divided into two parts: alerting for off-course deviation and alerting for path performance that has the potential for generating a collision situation.

Should an airplane (the ownship) deviate one dot or more (but less than two dots) from its nominal course, an advisory alert is issued to the deviating aircraft. An advisory alert is defined in SAE ARP1402/4, where pilot recognition is required (but not necessarily pilot action). A level 1 alert is typically called an "advisory."

Should the ownship deviate two dots or more from its nominal path, a caution alert is issued. A caution alert is defined in SAE ARP1402/4, where immediate pilot attention is required. A level 2 alert is typically called a "caution."

The other part of the flight path alerting addresses information to aid in avoiding collisions in the event that the ownship strays from its course and approaches the adjacent aircraft in a threatening manner (or has the potential of generating a collision condition, e.g., a turn-rate that could produce an intersecting flight path with the adjacent aircraft). For this document, this type of alert is defined as a "path" alert. An ownship hosted, onboard alerting algorithm uses state information from the traffic on the parallel approach, transmitted by ADS-B or an equivalent system, to detect situations where the potential path of the ownship may be threatening the adjacent traffic. If this situation occurs, the onboard alerting system generates a caution alert as this situation begins to evolve. This alert is intended to heighten the crews' awareness of their flight path management situation.

As the path performance and collision danger becomes more imminent, a warning alert is generated. In this situation, the annunciation of this warning alert requires the flight deck crew to execute an EEM.

6.2 Traffic Intrusion

The second alerting aspect of AILS addresses information to aid in avoiding collisions in the event that the parallel traffic strays from its course and approaches the path of the ownship in a threatening manner. An ownship hosted, onboard alerting algorithm uses state information from the traffic on the parallel approach, transmitted by ADS-B or an equivalent system, to detect threatening aircraft and provide an onboard alert to the threatened aircraft. The onboard alerting system generates a caution alert as a threatening situation begins to evolve. This alert is intended to heighten the crews' awareness of the traffic situation. No crew action is required for this alert.

As the danger becomes more imminent, based on the computations associated with the alerting algorithms, a warning alert is generated. The annunciation of this warning alert requires the flight deck crew to execute an EEM.

7.0 Emergency Escape Maneuver (EEM)

The Emergency Escape Maneuver (EEM) is an immediate, accelerating, climbing turn away from the intruding aircraft and the close parallel runway. The turn is to a heading change of 45 degrees from the final approach course. The EEM procedure will be published on the approach plate and is different than the missed approach procedure but may utilize the same holding fix.

8.0 Alerting Presentations

Alerting presentations follow the specifications as described in SAE ARP1402/4. Traffic symbology that is presented on the ND follows the convention of SAE ARP1402/10.

The following table summarizes the AILS alerts and their representations. The representations will be further described in the following sections. For the purpose of this paper the terms PFD and Electronic Attitude Direction Indicator (EADI) are considered to be interchangeable.

An example of a simplified PFD and ND in a nominal configuration (no alert) is shown in figure 3. In this example, the ND is presenting traffic on the parallel approach using traditional TCAS symbology.

Alert State	Level	Representation		Description
		visual	audio	
localizer	advisory	LOCALIZER		OS off by 1 dot
localizer	caution	LOCALIZER		OS off by 2 dots
path	caution	PATH		OS off path
traffic	caution	TRAFFIC		traffic off path
path	warning	flashing CLIMB TURN	CLIMB TURN	OS off path
traffic	warning	flashing CLIMB TURN	CLIMB TURN	traffic off path

8.1 Flight Path Management

Figure 4 shows an example of the displays with an advisory localizer alert, indicating an abnormal deviation of the ownship from its nominal course. In this example, the deviation is approximately one and one-quarter dots. To present this type of alert, the ownship symbol on the ND, the localizer scale, localizer pointer, and the “LOCALIZER” alphanumeric symbology on the PFD are all displayed in cyan.

To provide an indication of off-track localizer performance relative to a caution alert, the visually presented alert information is displayed with amber symbology on both the PFD and the ND. Figure 5 illustrates a caution alert. To present this type of alert, the ownship symbol on the ND, the localizer scale, localizer pointer, and the “LOCALIZER” alphanumeric symbology on the PFD are all displayed in amber. The display formats are presented in more detail in a later section.

In a similar manner, potential off-path conditions that may led to a possible collision situation, defined as caution and warning path alerts, are also provided. To provide an indication of ownship potential off-track performance relative to a caution alert, the visually presented alert information is displayed with amber symbology on both the PFD and the ND. This alert advises the flight deck crew to maintain a tighter adherence to path tracking. For the warning alert, a synthetic voice message is also presented with “Climb Turn, Climb Turn, Climb Turn.” The flight crew is required to take corrective actions for a warning alert. The display formats used to present this information are presented in more detail in a later section.

8.2 Traffic Intrusion

All caution alerting symbology for traffic intrusion, where the adjacent aircraft is threatening ownship, are presented in amber. An example of the flight deck displays for a caution alert is shown in figure 6. The word "TRAFFIC" is displayed in the center area of the PFD. On the ND, the traffic symbol for the parallel airplane changes to an amber filled circle in accordance with TCAS conventions. The flight crew is not required to take corrective actions for a caution alert.

All warning alerting symbology for traffic intrusions are presented in red. Figure 7 illustrates the display features for a warning alert. The words "CLIMB TURN" are displayed in the center area of the PFD. On the ND, the traffic symbol for the parallel airplane changes to an red filled square in accordance with TCAS conventions. In addition to the visual display, a synthetic voice message is presented with "Climb Turn, Climb Turn, Climb Turn." The flight crew is required to take corrective actions for a warning alert.

9.0 Summary of AILS Research Results to Date

The concept design team at LaRC completed a fixed base simulation test of the initial AILS concept in May 1996. In this test, sixteen pilots flew 56 parallel approaches with approximately one third of the cases presenting collision or near miss threats. The key test parameters in evaluating the concept were the reaction times of the pilots in executing the turn maneuver and the closest approach distance. Parallel approaches spaced 3400 and 2500 ft. apart were examined in this initial study. The test findings show that, under the conditions tested, all of the pilots' reaction times were well under the two seconds targeted by the LaRC design team. No trials resulted in violations of the 500 ft. minimal separations used for defining near misses. The mean miss distance measured was in access of 1900 ft., with the closest encounter of 1183 feet.

A second phase of testing was completed in July 1996 at LaRC. This follow-up test included new alerting algorithms and modifications to the displays based on observations and pilots' comments from earlier tests. Runway lateral spacing was reduced to 1700 ft. and 1200 feet. Eight, two-member, airline crews were used in the second phase. The results were favorable for the 1700 ft. runway separation, with no encounters closer than the targeted 500 ft. miss criteria. The 1200 ft. case resulted in one encounter closer than 500 feet. Two dimensional near missed criterion was used and was regarded as questionable by the design team, when the current experimental AILS technology is used.

A study at NASA Ames Research Center (ARC) was completed in August 1996 and explored the application of TCAS concepts to the close parallel runway approach problem. This study showed that a display based on the TCAS formats, but enhanced with a higher resolution ND and specially designed alerting algorithms, resulted in better performance than the TCAS implementation using a conventional ND format. This study at ARC investigated an autopilot coupled approach, in contrast with the manual mode used in the LaRC studies, and addressed the 4300 ft. and 2500 ft. runway spacing cases. The performance with the enhanced display features and alerting algorithms resulted in no near misses and good pilot evaluations.

Initial flight testing of the concept was conducted on the NASA 737 airplane in the spring of 1997. The tests were conducted to confirm that pilots could fly the airplane to the required navigation performance in a variety of wind conditions. The pilots rated the required task as acceptable and not requiring an excessive additional workload.

When interpreting these results, it is important to realize that they show the feasibility of the AILS concept in initial testing in a research simulator environment and minimal flight validation. Significant additional testing and validation is required before a concept of this nature could be implemented in the NAS.

The AILS concept can be implemented in a flight deck using display formats compatible to the type of flight deck involved. Two examples were selected for use in developing the concept at LaRC, centering on providing the flight information needed by the pilots on the PFD and on the ND in a generic "glass" flight deck implementation.

Figures 2a,b show the PFD and ND used in the concept development studies at LaRC in their nominal configuration, with no modifications made to support the AILS concept. The example display formats were derived from this configuration by adding AILS specific display information symbols. The two display formats were similar with the differences occurring on the ND. Also, flight director guidance for the EEM was included in some of the evaluation. The two example AILS display formats are referred to as, (1) the Modified Conventional Display (MCD) which used a traditional 10 NM range scale on the ND, and (2) the Enhanced Display (ED) which used a specially added 2 NM range scale on the ND. Examples of the MCD format are shown in figures 8a,b for a condition with alerts activated. Examples of the ED format are shown in figures 9a,b for a condition with alerts activated.

On the ND of both formats, an escape heading bug was automatically set on the compass rose at the AILS procedural escape heading 45 degrees off from the approach heading and in the direction away from the parallel traffic and runway. This bug was automatically set when the AILS algorithms were activated, which occurred before the airplanes start their descent. As shown in figure 16, LaRC explored the use of an Approach Path Boundary. The two dot localizer deviation resembles a rocketship in its plan view. The AILS alerting algorithms were activated at the point at which the airplanes enter the narrow linear ±500 ft. wide portion of the localizer path, 10 NM from the runway threshold. For this particular implementation the localizer data did not use a singular path boundary.

Besides the scale change between the MCD and the ED, the ownship symbol size was different. As shown in figures 9a,b for the ED, the symbol for the ownship was reduced in size and a 500 ft. radius, scaled circle encloses the arrowhead shaped aircraft symbol. The 500 ft. circle represents the protected airspace around the ownship for avoiding a near miss. In the case of the 10 NM range scaling of the MCD format, the 500 ft. radius circle would be too small to be a meaningful display symbol; therefore it was not presented.

10.0 Roles, Responsibilities, and Procedures

10.1 General

The AILS concept is procedures based. In designing the AILS procedures, the following considerations were employed:

The role of the pilot(s) will center on performing the following functions:

1. Confirm that the AILS system is operating properly prior to accepting responsibility for separation.
2. Accept responsibility for lateral separation when accepting a clearance for the AILS approach.
3. Fly within the boundaries of the approach corridor at the appropriate RNP.
4. Execute an EEM if an incident transpires.
5. Relinquish lateral separation responsibility back to ATC after executing an EEM.

Responsibilities for separation must be clear at all times during the process:

1. ATC will be responsible for separation as the turn on to final is made, during which time a minimum of 1000 ft. vertical separation will be maintained. This is prior to issuing an approach clearance.
2. The flight crew will be responsible for lateral separation from traffic on the parallel approach after an AILS clearance is issued and accepted.
3. Longitudinal or in-stream separation between aircraft is the responsibility of ATC throughout the approach.
4. If for any reason the AILS approach is terminated (i.e. missed approach, go-around, or EEM), ATC will resume separation responsibility.

If an AILS intrusion warning occurs, the flight deck crew will:

1. Execute the prescribed EEM.
2. Revert to TCAS resolution for collision avoidance.
3. Relinquish separation responsibility to ATC, who will immediately accept the transfer, barring disabling circumstances where the ATC displayed targets are merged.
4. Follow ATC instructions.

Wake turbulence issues will be addressed by the existing separation standards (see Appendix A). In general,

1. Adherence to longitudinal in-trail separation standards is required.
2. Initial applications of the baseline technology will limit the AILS applications to approach paths that are laterally spaced 2500 ft or greater.
3. Flight deck centered methods other than the baseline AILS concept may be applied for laterally closer approach operations, such as the 750 ft. runway spacing at San Francisco. Processes under consideration include segmented, offset, and paired/staggered approaches. All of the constraints and concerns of these variations may not be the same as those for the

baseline approach. Limited discussions of these variations from the baseline will be presented in this document.

10.2 Flight Deck

10.2.1 General Requirements

The airborne equipment and procedures described below are designed for a "glass" flight deck. Similar, complementary equipment and procedures would be used in an electromechanical, retrofit application.

Airborne equipment unique to this system includes:

- Receiver for DGPS approach path.
- ADS-B transponder equipment with a refresh rate of one -half second.
- Modified ND display to provide an additional 2 NM scale.
- PFD display modified to incorporate AILS requirements.
- Engine Indication and Crew Alerting System (EICAS) modified to enunciate warnings required by AILS.
- Flight Management Computer (FMC) database and logic modified to include AILS approaches.
- Electronic “handshake” protocol to provide ATC with necessary information and to insure proximate aircraft are on the correct approach path.

10.2.2 General Procedures

When advised by ATC of the AILS approach in use, the flight deck crew will select the appropriate approach from the menu on the FMS APPROACH page, verify, and EXECUTE. This action by the flight deck crew causes the following operational changes:

- Data link is established with suitably equipped proximate aircraft.
- Verification of correct runway selection is made by the AILS system.
- Special advisory equipment at ATC is activated.
- Transition parameters from TCAS to AILS are established.
- DGPS Required Navigational Performance (RNP) is confirmed by AILS.
- Special ND map scale (2 NM) is enabled for the approach.

EICAS error messages associated with AILS approaches are:

HANDSHAKE FAULT.................Error detected with data link between proximate aircraft
DGPS FAULT.............................Error detected with Differential GPS signal
AILS SYSTEM...........................Error detected with aircraft hardware or software

In the event of a error message, the flight deck crew should confirm and re-select the appropriate AILS runway in the Flight Management System (FMS). The flight deck crew can take no other corrective action. If the error message continues to be displayed prior to starting descent, advise ATC to discontinue AILS approach and request clearance for other type approach. If an error message is displayed after commencing descent, execute a missed approach and advise ATC.

Candidate Airplane Flight Manual (AFM) additions are provided in appendix B.

10.2.3 Displays

The AILS concept can be implemented in a flight deck in any number of different display formats. The details of the implementation will depend upon the type of flight deck involved in the application. One example will be described in this section.

10.2.3.1 Information Requirements

To support the AILS concept, the flight deck displays should perform the functions listed below. In this list the items preceded by an asterisk (*) are regarded as requirements, the other items are recommended but their exclusion is not expected to impede the safe operation of the system. The display should:

*1. Provide a positive indication of when the AILS system is operating.

*2. Provide a positive indication for system malfunction or degraded operation.

*3. Show the traffic being monitored.

4. Show the ownship approach path.

5. Show progress along the nominal approach path.

6. Show the relative position of traffic.

*7. Present an alert for ownship off-path operation.

*8. Present a warning alert when ownship violates its airspace boundaries.

*9. Enable monitoring parallel traffic for threatening conditions.

*10. Support the monitoring of multiple airplanes along the close parallel runway approach path.

*11. Present an alert for the potential loss of lateral separation.

*12. Present a break-out command with a warning traffic alert.

*13. Present an indication of the EEM turn heading.

*14. Provide a means to reset the alerts.

*15. Provide aural alerts for abnormal conditions per SAE ARP1402/4.

*16. Use SAE ARP1402/4 color and format standards in presenting alerts.

*17. Identify the traffic being monitored.

*18. Provide a clear indication of the cause of the alert so that the appropriate corrective action can be taken.

*19. Clearly distinguish the AILS alerts from other alerts.

Per the above requirements, the display should present the AILS alerts as they are described in the alerting algorithm section of this document. There are four states involved for the alerts which the AILS display formats should clearly present.

1. Normal operations- This is a level 0 (level zero) condition in the SAE ARP1402/4 standard and is when the system state is functioning normally with no safety threats.

2. Advisory-This is a level 1 alert condition in the SAE ARP 1402/4 standard. The operator is advised of a potential problem not regarded as an actual threat. Use of the color cyan is the industry standard for displaying information related to this state.

3. Caution - This is a level 2 alert condition in the SAE ARP1402/4 standard. The operator is informed of the problem but no corrective action is required. Use of the color amber is the industry standard for displaying information related to this state.

4. Warning - This is a level 3 alert in the SAE ARP1402/4 standard. Immediate corrective action is required. Display of related information and symbols in red is the recommended practice and industry standard in this alert status.

10.2.3.2 Candidate Symbology for Flight Path Management

Figures 2a,b show the PFD and ND used in the concept development studies at LaRC in their nominal configuration, with no modifications made to support the AILS concept. The PFD includes aircraft attitudes, speed, altitude information, glide slope and localizer deviation information, as well as flight director pitch and bank command bars. The ND presents a plan view of the airplane included on a scaled map in a heading up format. It also shows the location of navigation aids and displays a compass rose.

A generic and much simplified example of a PFD and ND display format for an advisory alert for a localizer deviation is shown in figure 4. As previously discussed, the color cyan is associated with an advisory alert. On the PFD, the word “LOCALIZER” is displayed in the center portion of the display and the localizer scale is changed from its original white color to cyan to assist the pilot in recognizing the nature of the problem (localizer deviation) causing the caution alert condition. In addition, the ownship symbol is changed from white to cyan on the ND.

An example of a caution alert for a localizer, lateral path deviation is shown in figure 5. As previously discussed, the color amber is associated with a caution alert. On the PFD, the word “LOCALIZER” is displayed in the center portion of the display and the localizer scale is changed from its original white color to amber to assist the pilot in recognizing the nature of the problem (path tracking) causing the warning alert condition. In addition, the ownship symbol is changed from white to red on the ND.

In a manner similar to the caution localizer alert, an example of a caution alert for unsuitable path tracking is shown in figure10. On the PFD, the word “PATH” is displayed in the center portion of the display. In addition, the ownship symbol is changed from white to amber on the ND.

An example of a warning alert for unsuitable path tracking, which is now generating a imminent collision or near-miss situation, is shown in figure 11. On the PFD, the words “CLIMB TURN” are displayed in the center portion of the display. The words "CLIMB TURN" are used for this alert condition because the flight crew is to perform an EEM when this alert is presented. In addition, an aural announcement “Turn, Climb” repeated three times is presented. On the ND, the ownship symbol is changed from white to red.

10.2.3.3 Candidate Symbology for Intrusion Alerting

An example of a caution alert due to a potential traffic intrusion is presented in figure 6. An alphanumeric display of the word "TRAFFIC" is presented in the central portion of the PFD in amber. The parallel traffic symbol is shown in the ND deviated from its nominal path and colored amber.

An example of a warning alert due to a potential traffic intrusion is presented in figure 7. An alphanumeric display of the words "CLIMB TURN" are presented on the central portion of the PFD in red. In addition, an aural announcement "Climb Turn," repeated three times is presented. On the ND, the color of the traffic symbol and its information tag is changed from the amber of the caution condition to the standard warning color of red.

To aid the flight crew in performing the EEM, the ND presents an escape heading bug automatically when the AILS algorithms are activated. This escape heading bug is displayed on the compass rose at the AILS procedural escape heading (45 degrees from the approach heading in the direction away from the parallel traffic and runway).

A two nautical map scale was provided on the ND to aid the pilots' in better visualizing the traffic situation.

10.2.3.4 Candidate Symbology for Electromechanical Flight Deck Retrofit Applications

Under development.

11.0 Alerting Algorithms

AILS alerting concept includes alerts to draw attention of the pilots to excessive lateral deviations from the centerline of their approach path as well as possible threats to protected airspace around an aircraft by adjacent traffic. Note that lateral deviation alerts already exist in some glass cockpits. Displaying the color of the Course Deviation Indicator (CDI) in amber if the aircraft strays more than one 'dot' from the approach centerline and red for more than two 'dot' deviations manifests these alerts. The AILS concept extends that philosophy to all aircraft operating in the AILS regime. The algorithms that generate lateral deviation alerts simply compare the value that drives the CDI, or an equivalent computed parameter, with specified thresholds and sets appropriate flags for use by a display controller. The 'one-dot' and 'two-dot' alerts are two of the six classes of AILS alerts.

Possible threats of aircraft intrusions are evaluated by examining the predicted relative paths of aircraft pairs based on the aircraft state information exchanges between the aircraft. First, the predicted path of the "ownship" relative to the "adjacent" traffic aircraft is examined to determine if the ownship is a threat to the adjacent. The threat is based on whether or not the possible paths predicted for ownship can penetrate specified vertical and horizontal protected airspace thresholds within specified times. Examples of protected airspace boundaries in the horizontal plane for the four classes of AILS threat evaluations and a linear AILS path boundary for lateral deviation alerts are depicted graphically in Figure 12. Predicted penetration of the first (and numerically largest) set of altitude, horizontal, and time threshold values causes flags to be set indicating an AILS Class 1 (caution) alert which, in turn, is to be used to generate a caution alert in the cockpit. Predicted penetration of a smaller protected airspace volume generates an AILS Class 3 (warning) alert and corresponding warning alert in the cockpit. A scenario of AILS Classes 1 and 3 threat evaluations is presented in Figure 13.

Next, the ownship on-board software evaluates the threat of a possible intrusion from adjacent traffic using somewhat smaller thresholds than those used for ownship threat to adjacent traffic evaluations. Predicted penetrations of protected caution and warning airspace by an adjacent traffic aircraft generate AILS Class 2 and Class 4 alert flags, respectively. Those flags are then used to generate caution and warning cockpit alerts. A scenario of AILS Classes 2 and 4 threat evaluations is presented in Figure 14.

Both aircraft of a given pair evaluate threat possibilities using similar but not necessarily identical aircraft state data. This feature of AILS forms a quasi-redundant protection system of the four classes of AILS threat evaluations in each aircraft of a pair. The threshold values are chosen such that in the event of a warning threat, the pilots of the aircraft causing the threat are alerted before it is necessary for the protected aircraft to break off its approach. A flow chart of the evaluation process in the AILS threat algorithms for cylindrical protected airspace is presented in Appendix C1 and C2.

The current implementation of the AILS algorithms assume that the protected aircraft is centered in the protected airspace boundaries which are elliptical in shape. The eccentricity of the ellipse is controlled by specified cross-track and along-track parameters. Another possibility for the aircraft location within the protected airspace is to displace it from the center. It may be desirable to have more protected airspace ahead of the aircraft than behind because pilots are usually more concerned with that area. An example is shown in Figure 15 where the aircraft is displaced half-way back in the protected airspace which is twice as long as it is wide and where the cross-track distance to the boundary at that location is a specified minimum, in this case 750 feet. Note that the minimum distance from the aircraft location to the boundary is about 700 feet.

12.0 Systems Safety

The goal of AILS is to maintain a safety level that is equivalent to that of the current ATC system. To provide this level of safety, both the frequency and the accuracy of the emergency escape maneuvers (EEM) must be controlled. The former is needed to ensure that the number of EEM's is very low and to ensure the AILS system provides the necessary improvement in terminal area productivity. The EEM itself must be robust enough to insure that the FAA defined near miss distance of 500 ft. separation is rarely, if ever, compromised.

In statistical terms, the AILS system is designed so that the joint probability of the occurrence of an EEM and the probability of an unsuccessful EEM is less than 10^{-9}. The two parts of the AILS system are designed so that the probability of an EEM is 10^{-7} while the probability of an unsuccessful EEM is less than 10^{-3}. The extra order of magnitude insures that the system will provide the necessary level of safety even if one of the components falls short of its design criteria.

In order to ensure that the number of EEM's is very rare, each of the following AILS system errors must be controlled so the joint probability of an EEM does not exceed 10^{-7}.

1. Navigational signal errors- that cause an unnecessary EEM by either aircraft.
2. Mechanical problem- in either aircraft that causes an unnecessary EEM.
3. Incorrect ATC clearance- in which the controller causes an EEM by clearing either the aircraft for an AILS approach to the wrong runway or vectors the aircraft through a final approach course.
4. Communication errors- between ATC and either aircraft that result in an unnecessary EEM.
5. Pilot errors- situations in which the flight deck crew of either aircraft cause an unnecessary EEM by selecting the wrong AILS frequency for the approach.
6. Tracking errors- that cause an EEM. Either the flight deck crew or the autopilot can cause these tracking errors. Tracking errors include flight in the maximum crosswind and lateral wind shear that is authorized for the approach.
7. False-positive turn and climb alerts- that result in an unnecessary EEM.

In order to ensure that the number of unsuccessful EEM's will be rare, the following AILS system errors must be controlled so the cumulative probability of an unsuccessful EEM will be less than 10^{-3}.

1. Signal errors- situations in which the ADS-B signals are either delayed or not received causing a Near Mid Air Collision (NMAC).
2. Aircraft mechanical errors- Situations in which a mechanical problem in the alerting system of the evading aircraft causes an NMAC.
3. False-positive turn and climb alerts that result in an unnecessary EEM and an induced NMAC.
4. False-negative turn and climb alerts in which an EEM should have occurred regardless of the NMAC outcome.
5. True-positive turn and climb alerts in which an induced NMAC occurs even though the AILS system reacted correctly. This includes, but is not limited to, situations involving conflicting alerts by multiple intruder aircraft, secondary turns by the intruder aircraft, and certain overtaking situations by the intruder.
6. True-negative turn and climb alerts in which an NMAC occurred even though no turn and climb alert was generated and the AILS system worked correctly. This includes, but is not limited to, situations involving late maneuvering by the intruder aircraft, intruder angles greater than 30°.
7. Communication errors- Communication problems between ATC and the evading aircraft, causing an NMAC.
8. Pilot errors- Situations in which the pilot is slow to react or makes an improper EEM, causing a NMAC. This includes, but is not limited to, slow reactions times, misinterpretation or confusion concerning the displays or alerts, slow roll or pitch rate, inadequate bank angle, and incorrect EEM heading or altitude.

13.0 Open Issues

Under development.

14.0 Study Recommendations

Under development.

15.0 Alternate Operations Concepts

15.1 Segmented Approaches

The segmented AILS approach procedure allows aircraft to use flight management system (FMS) capabilities along with DGPS to fly a path that converges to a parallel runway spaced as close as 700 feet. It requires the aircraft to be in VMC and the airport to be in VFR conditions before the minimum certified AILS capability is violated. If the AILS process is approved down to 2500 ft. runway spacing, then by the time the aircraft on the segmented approach comes as close as 2500 ft. from the parallel runway extended centerline, it must have entered VMC conditions and have both the runway and traffic in sight. Handoff of responsibility for separation is made to the flight deck crew when the approach clearance is given and will continue into visual condition.

The question of what procedures will be used as the AILS process is terminated in the vicinity of the 2500 ft. lateral separation from the parallel approach path has been examined. The nominal expectation is that the flights will continue under visual approach protocols after being cleared to land. The condition for clearing an aircraft to land is that the leading aircraft or airport is in sight. An aircraft will have to maintain visual separation from the other traffic prior to reaching the 2500 ft. lateral separation point.

Use of the segmented AILS approach will require that aircraft are paired and staggered so that the aircraft on the offset approach path will be expected to see the aircraft on the straight-in path when it enters VMC. The aircraft on the straight-in approach will be positioned ahead of the one on the offset path. Following such a protocol, the flight deck crew on the offset approach, would be required to see the traffic on the straight-in path that has been setup and maintained in the leading position in the pair.

For further details on segmented AILS approaches refer to The Analysis of the Role of ATC in the AILS Process document.

15.2 Offset Approaches

Under development

15.3 Paired/Staggered Approaches

Under development.

16.0 Summary of Current AILS Concept

16.1 Procedures

The AILS concept can be partitioned into two primary aspects. The first is flight path management, where accurate navigation is required to keep each aircraft on its respective course. This is the primary safety consideration for the AILS concept. The second aspect is alerting for an intrusion, where alert are generated for situations where the parallel traffic strays from its course and approaches the path of the ownship in a threatening manner.

- The AILS concept is procedures based.
- ATC places the aircraft in a position where an AILS clearance can be issued.
- The flight deck crew accepts responsibility for lateral separation when accepting a clearance for the AILS approach.
- The flight deck crew maintains the aircraft within the boundaries of the approach corridor at the appropriate RNP.
- The Emergency Escape Maneuver (EEM) is an immediate, accelerating, climbing turn away from the intruding aircraft and the close parallel runway. The turn is to a heading change of 45 degrees from the final approach course.
- The flight deck crew executes an EEM if an incident transpires.
- Upon execution of an EEM, the flight deck crew will revert to TCAS resolution for collision avoidance.
- The flight deck crew relinquishes lateral separation responsibility back to ATC after executing an EEM.

16.2 Alerts

The AILS alerting algorithms are activated at the point at which the airplanes are on the final approach, 10 NM from the runway threshold.

Alerting is provided for flight path management, where accurate navigation is required to keep each aircraft on its respective course.

- Should an airplane deviate one dot or more (but less than two dots) from its nominal course, an advisory alert is issued to the deviating aircraft.
- Should the ownship deviate two dots or more from its nominal path, a caution alert is issued.
- Should an airplane have an unsuitable flight path, which may lead to a collision or near-miss situation, a caution alert is issued to the deviating aircraft.
- Should an airplane have an unsuitable flight path, which will lead to an imminent collision or near-miss situation, a warning alert is issued. The annunciation of this warning alert requires the flight deck crew to execute an EEM.

Alerting is provided for an intrusion, where alerts are generated for situations where the parallel traffic strays from its course and approaches the path of the ownship in a threatening manner.

- The on board alerting system as a threatening situation begins to evolve generates a caution alert. No crew action is required for this alert.

- As the danger becomes more imminent, based on the computations associated with the alerting algorithms, a warning alert is generated. The annunciation of this warning alert requires the flight deck crew to execute an EEM.

16.3 Displays

Alerting presentations follow the specifications as described in SAE ARP1402/4. Traffic symbology that is presented on the ND follows the convention of SAE ARP1402/10.

To provide an indication of localizer, off-track performance relative to an advisory alert:
- the ownship symbol on the ND is displayed in cyan.
- the localizer scale and localizer pointer are displayed in cyan.
- the “LOCALIZER” alphanumeric symbology on the PFD is displayed in cyan.

To provide an indication of localizer off-track performance relative to a caution alert:
- the ownship symbol on the ND is displayed in amber.
- the localizer scale and localizer pointer are displayed in amber.
- the “LOCALIZER” alphanumeric symbology on the PFD is displayed in amber.

To provide an indication of unsuitable flight path, which may lead to a collision or near-miss situation relative to a caution alert:
- the ownship symbol on the ND is displayed in amber.
- the “PATH” alphanumeric symbology on the PFD is displayed in amber.

To provide an indication of an unsuitable flight path which will led to an imminent collision or near-miss situation relative to a warning alert:
- the ownship symbol on the ND is displayed in red.
- the “CLIMB TURN” alphanumeric symbology on the PFD is displayed in red and is flashed (at a rate of 3 HZ) as a supplementary method to attract crew attention.
- a synthetic voice message is presented with “Climb Turn, Climb Turn, Climb Turn.”

To provide an indication of a traffic intrusion relative to a caution alert:
- the word “TRAFFIC” is displayed in the center area of the PFD in amber.
- the traffic symbol for the parallel airplane on the ND changes to an amber filled circle and its associated tags will change to amber.

To provide an indication of a traffic intrusion relative to a warning alert:
- the words “CLIMB TURN” are displayed in the center area of the PFD in red and is flashed (at rate of 3 HZ) as a supplementary method to attract crew attention.
- the traffic symbol for the parallel airplane on the ND changes to a red filled square and all its associated tags will turn to red.
- a synthetic voice message is presented with “Climb Turn, Climb Turn, Climb Turn.”

To aid the flight crew in performing the EEM, the ND presents an escape heading bug automatically when the AILS algorithms are activated. This escape heading bug is displayed on the compass rose at the AILS procedural escape heading.

A two nautical map scale was provided on the ND to aid the pilots’ in better visualizing the traffic situation.

References

[1] Koczo, S., “Coordinated Parallel Runway Approaches,” NASA Contractor Report NAS-19704, October 1996

[2] Waller, M., “The Analysis of the Role of ATC in the AILS Process,” NASA LaRC Report, May 1998

[3] Federal Aviation Administration, “Precision Runway Monitor Demonstration Report,” DOT/FAA/RD-91/5, February 1991

[4] Society of Automotive Engineers, “Flight Deck Alerting System (FAS),” SAE ARP-4102/4, July 1988

[5] Federal Aviation Administration, “Air Traffic Controllers Handbook,” DOT/FAA/Order 7110.65L, February 1998

Appendix A

Wake Turbulence Considerations for Arrival Aircraft to Close Parallel Runways

Wake turbulence is a safety consideration that affects separation standards (safe spacing of aircraft) for arrival aircraft. The current separation standards are stated in FAA Order 7110.65 (Reference 5), and shall be applied in all cases to insure the safe and orderly flow of air traffic. Separation is applied to arriving Instrument Flight Rules (IFR) aircraft operating in-trail to one runway or on approaches to close parallel runways. Parallel runways less than 2500 ft. apart are considered as a single runway because of the possible effects of wake turbulence. This means that ATC must use single runway separation for aircraft arriving to runways closer than 2500 feet.

Research has determined that the weight and wing span of an aircraft have direct effects in generating wake turbulence. That is, the heavier the aircraft the greater the strength of the wake turbulence. Consequently, the FAA has separated the aircraft into three classes depending on the wake vortices they produce. They are small, large and heavy, and a special class for Boeing 757 aircraft. Minimum radar separation distances have been established for in-trail arrival aircraft that are determined by the weight class of both the leading and the following aircraft. The current, standard radar separation criteria for in-trail arrival aircraft are:

Separate a large aircraft behind a large by 3 nautical miles.

Separate a small aircraft behind a small by 3 nautical miles.

Separate a heavy aircraft behind a heavy by 4 nautical miles.

Separate a large or heavy aircraft behind a B757 by 4 nautical miles.

Separate a small aircraft behind a B757 by 5 nautical miles.

Separate a large aircraft behind a heavy by 5 nautical miles.

Separate a small aircraft behind a heavy by 6 nautical miles.

Note: In-trail separation between certain aircraft may be reduced to 2.5 NM at airports that meet special criteria.

It is the air traffic controller's responsibility to ensure that these separation criteria are maintained at all times.

Aircraft on the same, or adjacent flight paths, are subject to hazardous flying conditions caused by the lateral and downward movement of vortices that are the most predominant parts of aircraft wake turbulence. Current considerations for wake turbulence will permit independent parallel approaches to runways laterally spaced no closer than 2500 feet. In the future, based on reasonable extensions of wake vortex quantification methodologies being developed and tested, the AILS process may be applied to parallel runways spaced closer than 2500 ft. apart. For the studies planned in fiscal year (FY) 99-00, the AILS procedure will be applied to parallel runways that are spaced 2500 ft. or more apart. This will preclude the need to establish one set of requirements for runways spaced 2500 ft. or more apart, and a second set for runways spaced less than 2500 ft. apart, e.g., 2000 ft. or 1700 feet. It is anticipated that initial AILS applications will look at airports where the runway spacing is 2500 ft. or greater.

Appendix B

Operating Procedures

ATC will vector or provide clearance to final approach in the conventional manner. Prior to receiving clearance for the approach, ATC will advise each aircraft of the type aircraft and relative position of the proximate traffic.

AILS APPROACH
Fly approach A/P or F/D
Fly normal missed approach A/P or F/D Fly EEM MANUAL ONLY. No autoflight guidance is provided.

Pilot Not Flying (PNF) FMS ARRIVALS........……………......………..…..AILS

Select AILS for the appropriate runway. Observe AILS ARMED is enunciated on the PFD. EICAS will display error message and approach guidance will be biased out of view if the system detects an error.

Captain (C), First Officer (F/O) …………..….APPROACH/LANDING BRIEFING
After receiving clearance for an AILS approach, the following items will be added to the normal briefing:
-Use of autopilot on approach
-PNF monitor proximate A/C position
-Emergency Escape Maneuver

Pilot Flying (PF), AUTOPILOT (AS DESIRED)................……………......ARMED

PF, AUTOTHROTTLE (AS DESIRED).....................……..……......ON
Although not mandatory for AILS approaches, use of autopilot and autothrottle is recommended

PNF, AILS ACTIVE........……..….ANNOUNCE
Activation of AILS is indicated by green AILS enunciation in PITCH and ROLL windows of PFD. Enunciations are enclosed in a box for 10 seconds. Map display changes to 2 NM scale.

PNF, PROXIMATE TRAFFIC........................…………....MONITOR

CAUTION

If AILS Conflict is enunciated (TURN, CLIMB, TURN, CLIMB), PF will accomplish the following procedure without delay:

PF, PNF GO-AROUND.......………….INITIATE

PF, AUTOPILOT......………........DISCONNECT

PF, AUTOTHROTTLES...……….......DISCONNECT
Pilot flying calls “EEM”, advance throttles to rated thrust and simultaneously initiate a climbing turn away from intruding traffic
-Target bank angle 30 degrees (above 400’)
- Target pitch VREF 30 plus 15 knots
- Target heading 45 degrees divergent
- Target altitude as published

PNF FLAPS (ON ORDER)..........……….........POSITION 20

PNF GO-AROUND.....………...........MONITOR
Pilot not flying will advise ATC of EEM as soon as possible.

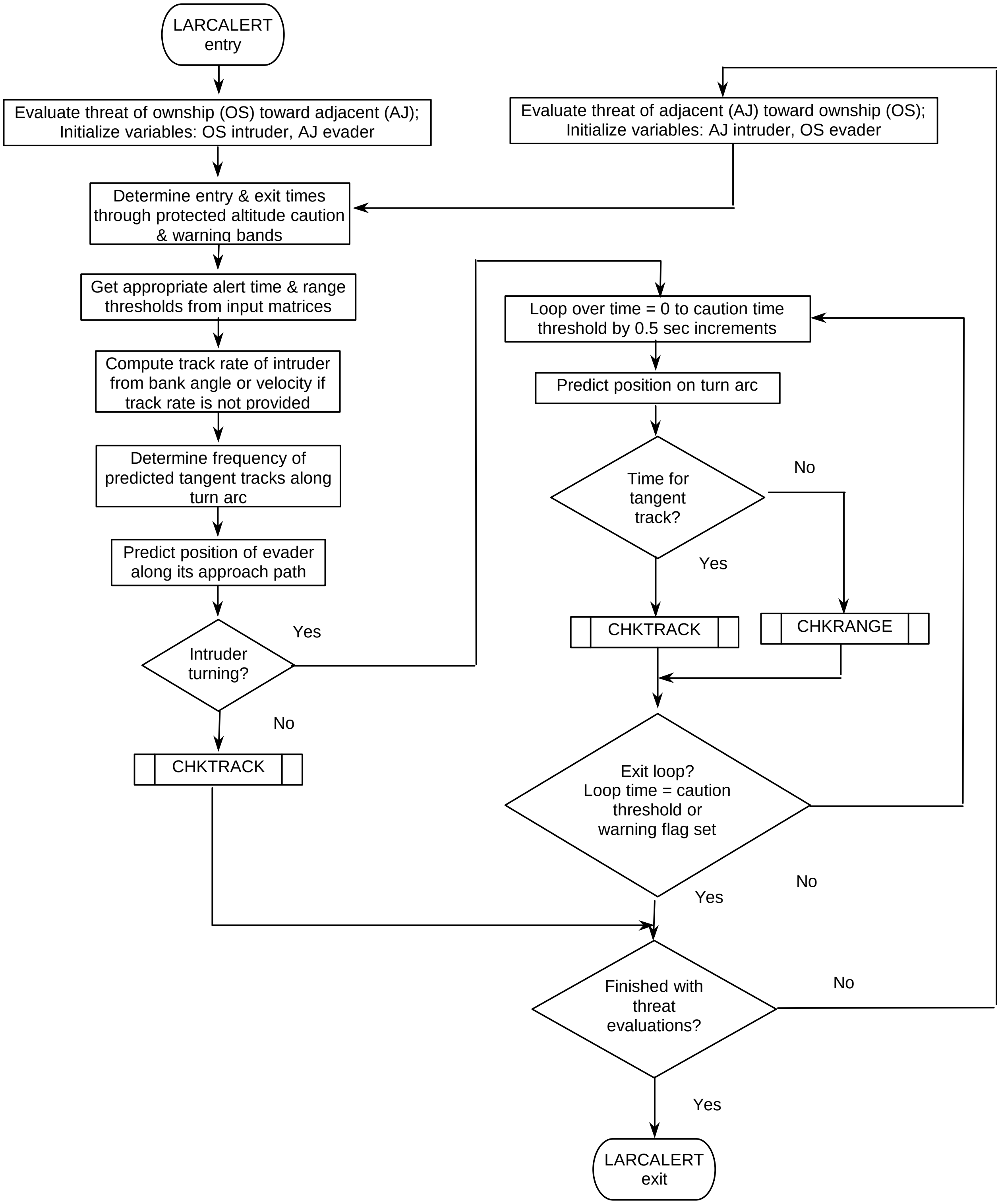
PNF GEAR (ON ORDER).......…………..........UP
Either pilot observes and calls positive climb. Pilot flying calls for gear up and pilot not flying retracts the gear.

PF PUBLISHED EEM ALTITUDE......................……………..MAINTAIN

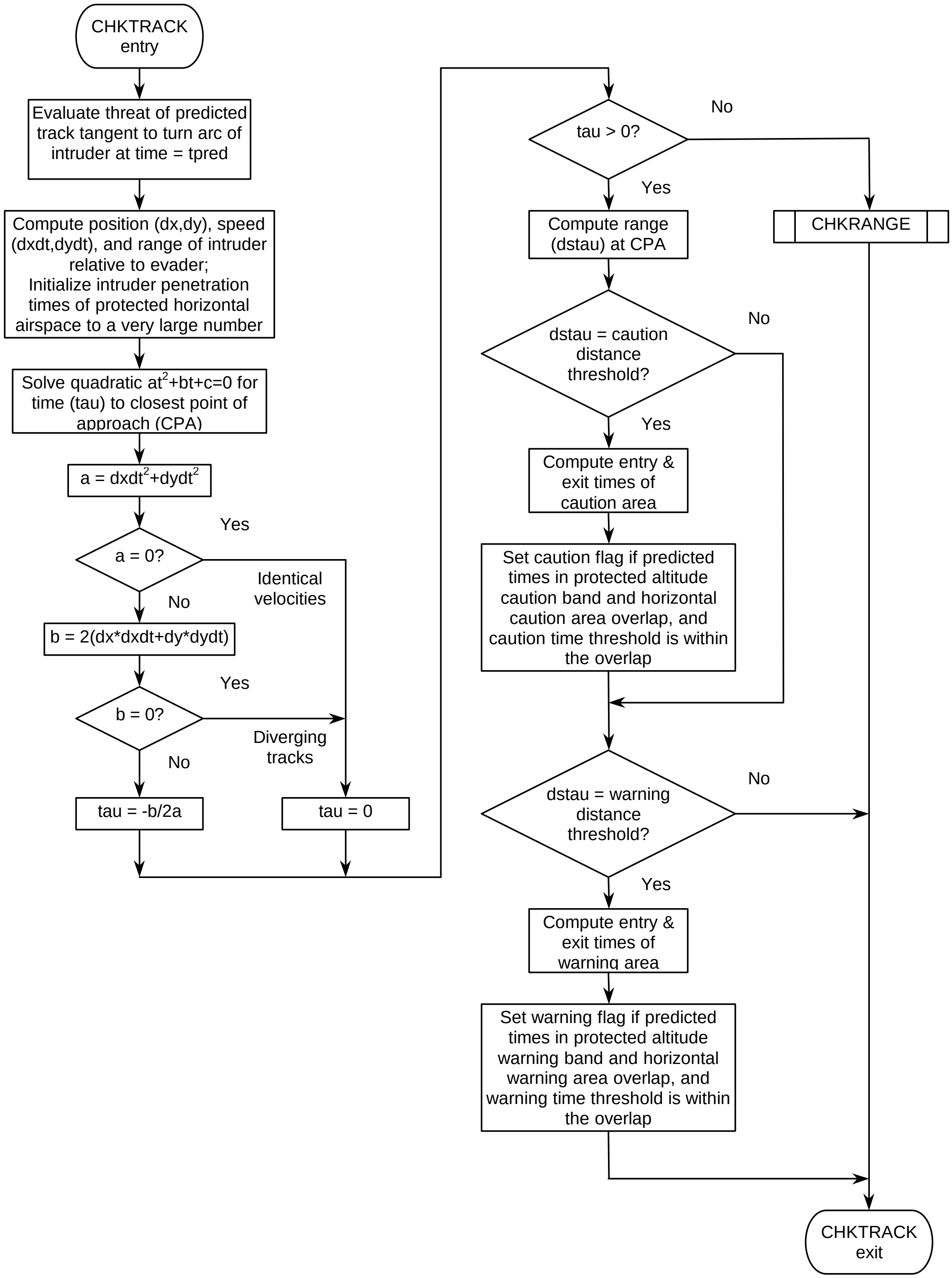
NOTE

Enunciation of AILS conflict causes system to revert to TCAS separation.

Appendix C



C1. LARCALERT Algorithm Flowchart



C2. CHKTRACK Algorithm Flowchart (Circular Protected Airspace)

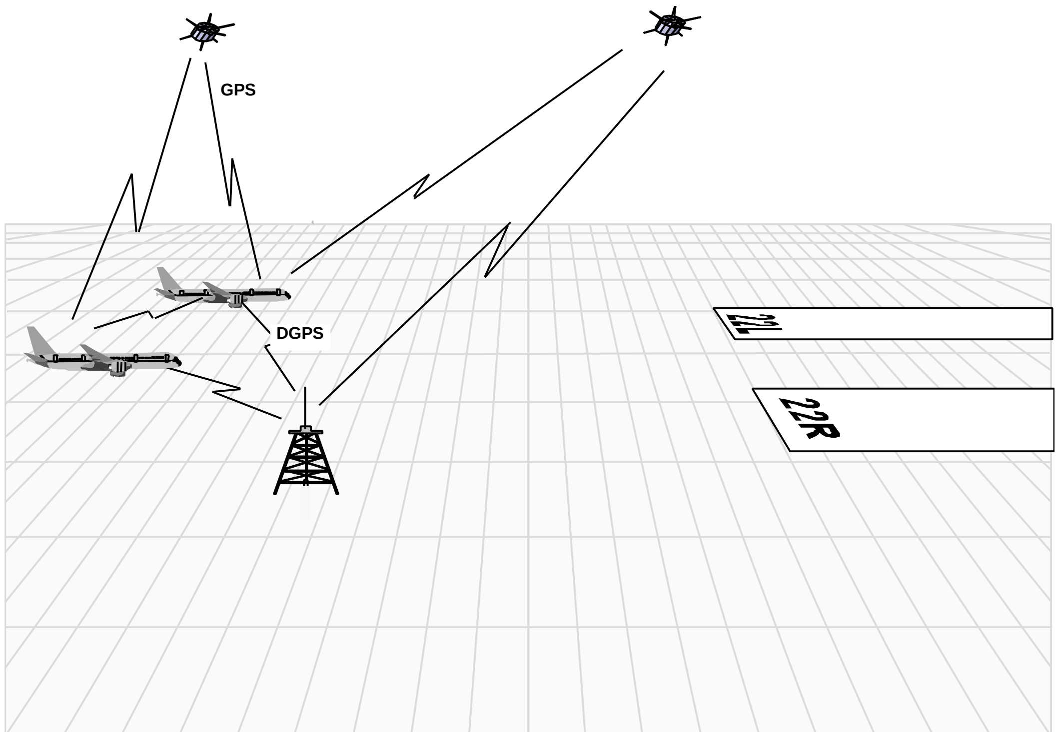


Figure 1. Basic AILS concept.

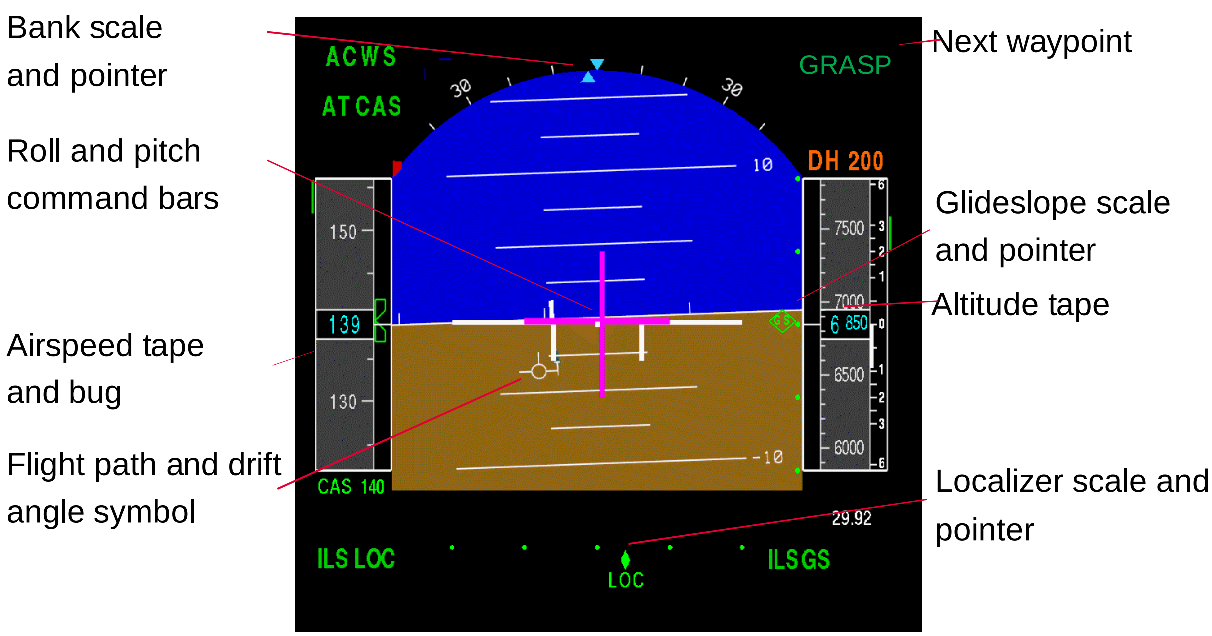


Figure 2a. PFD - nominal format

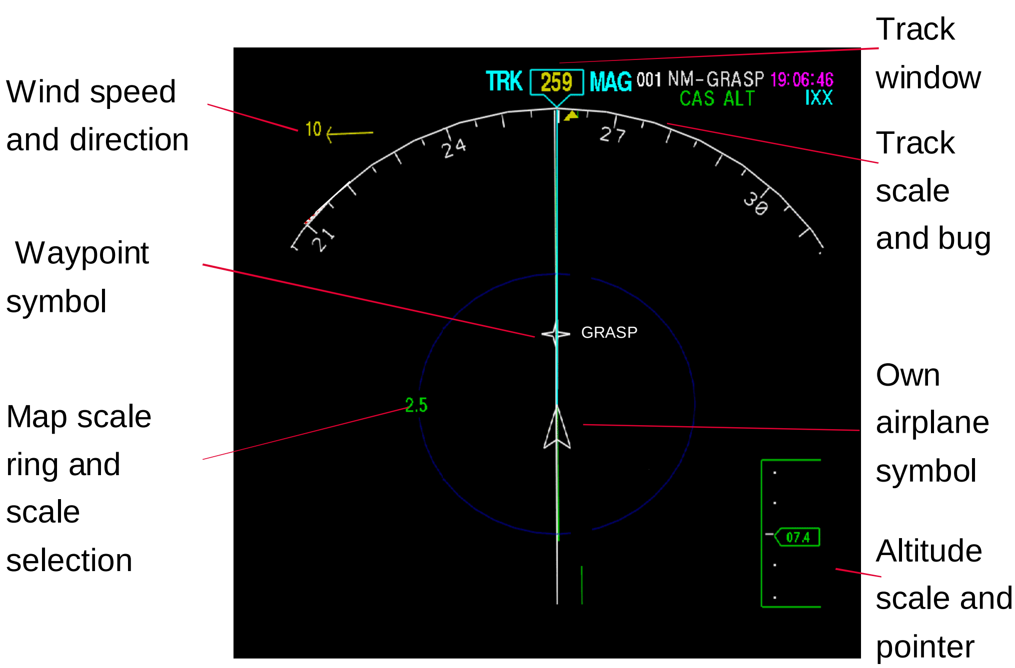


Figure 2b. ND - nominal format

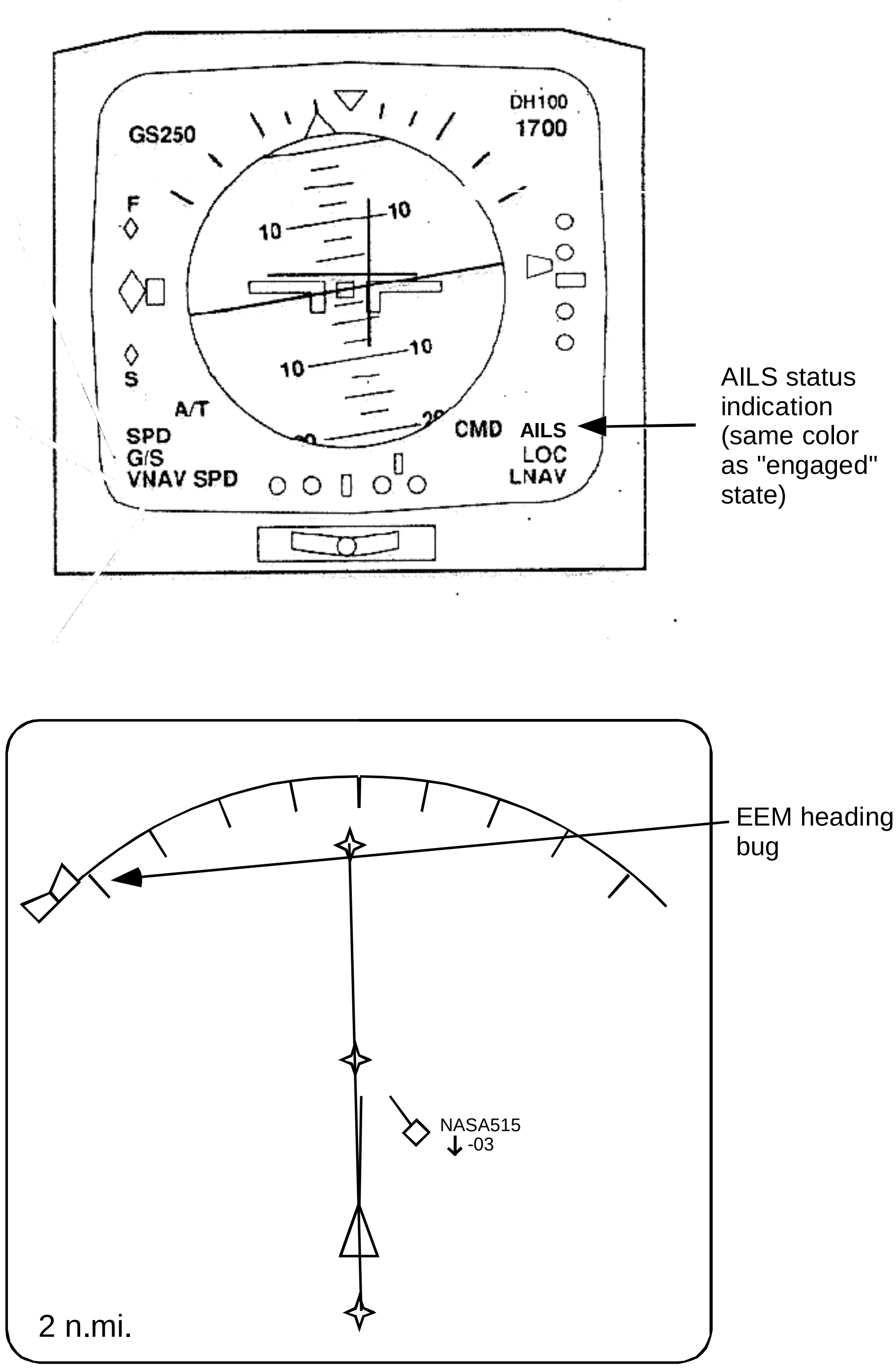


Figure 3. PFD and ND showing AILS operational status-nominal format

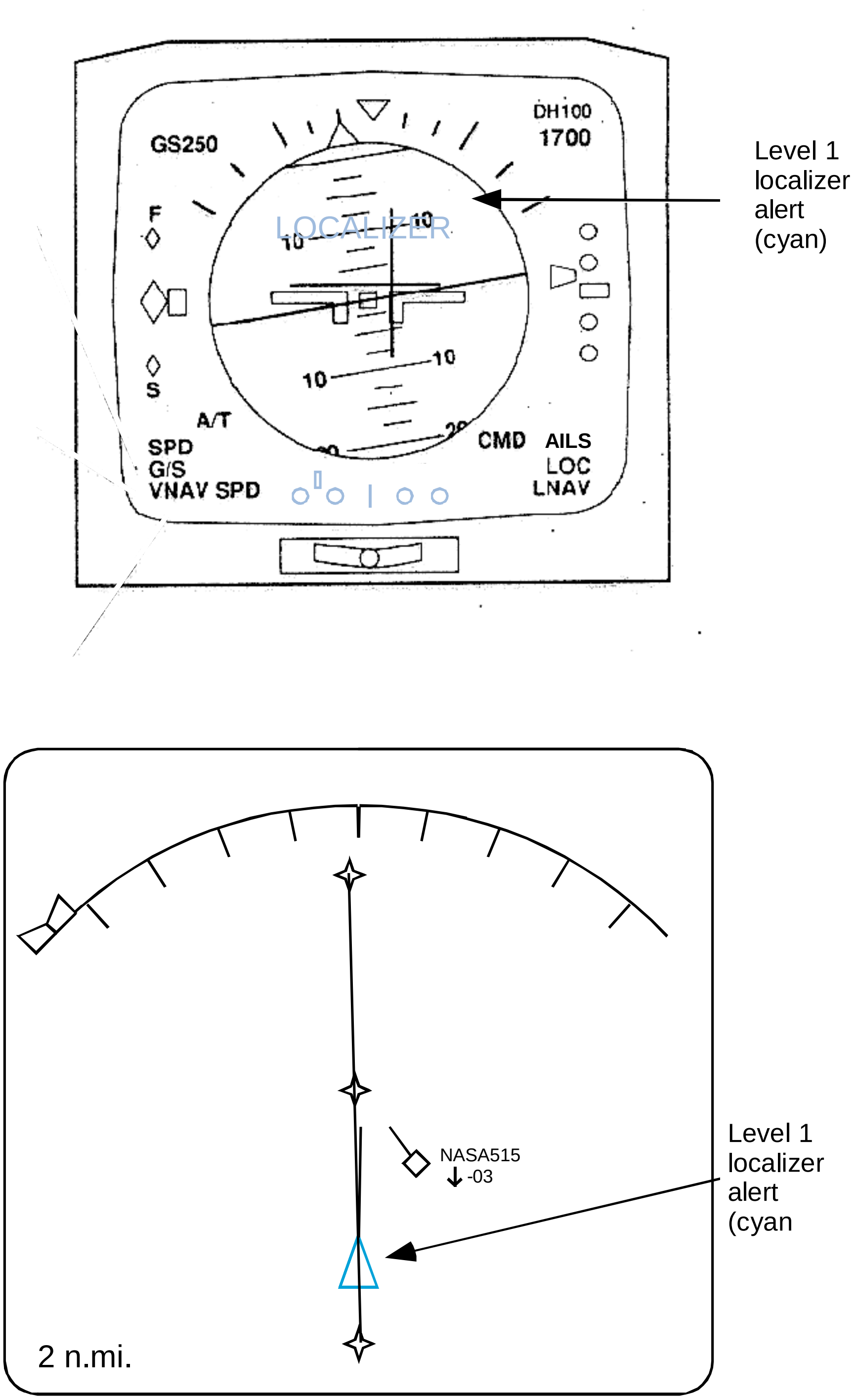


Figure 4. PFD and ND showing localizer advisory alert

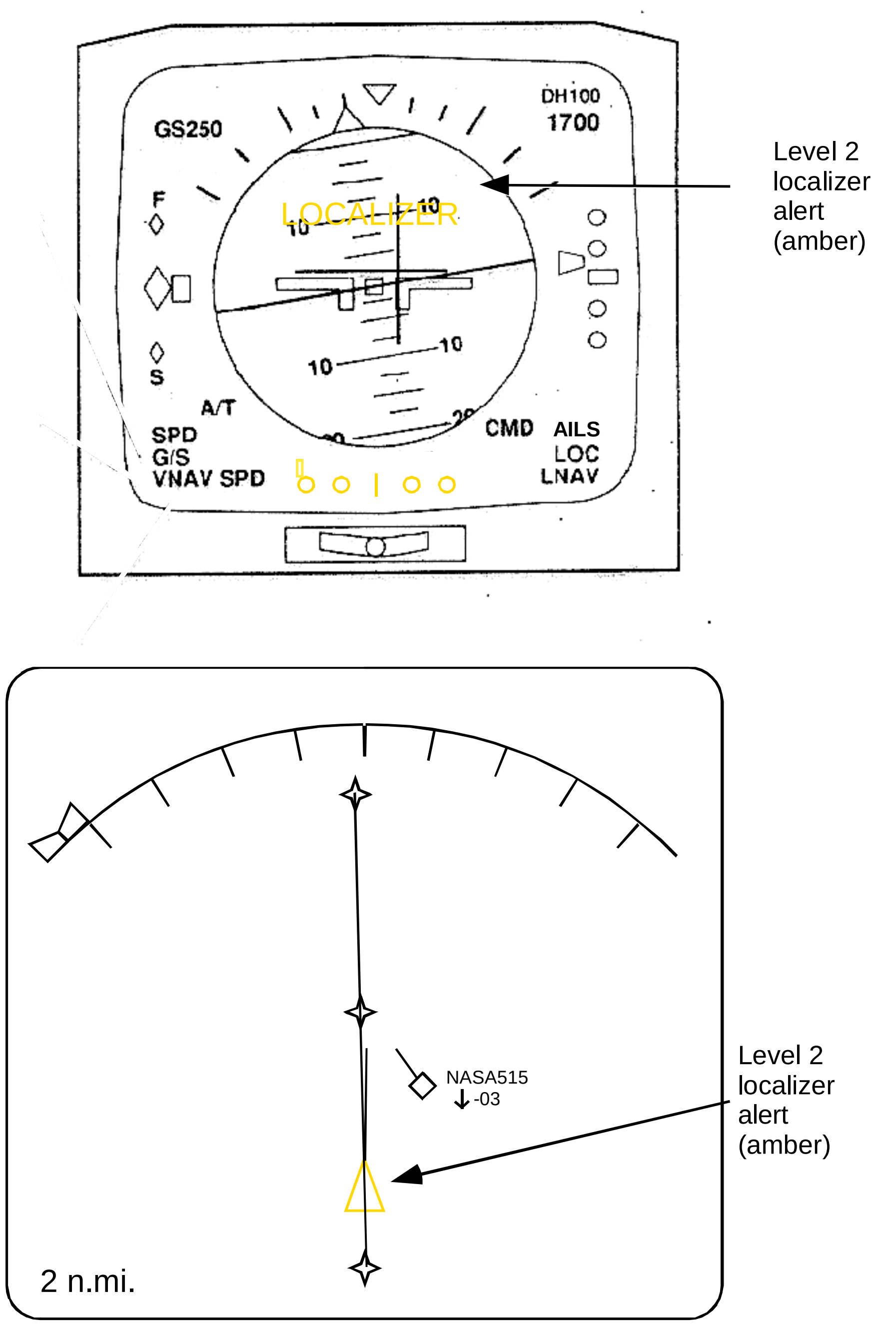


Figure 5 PFD and ND showing localizer caution alert

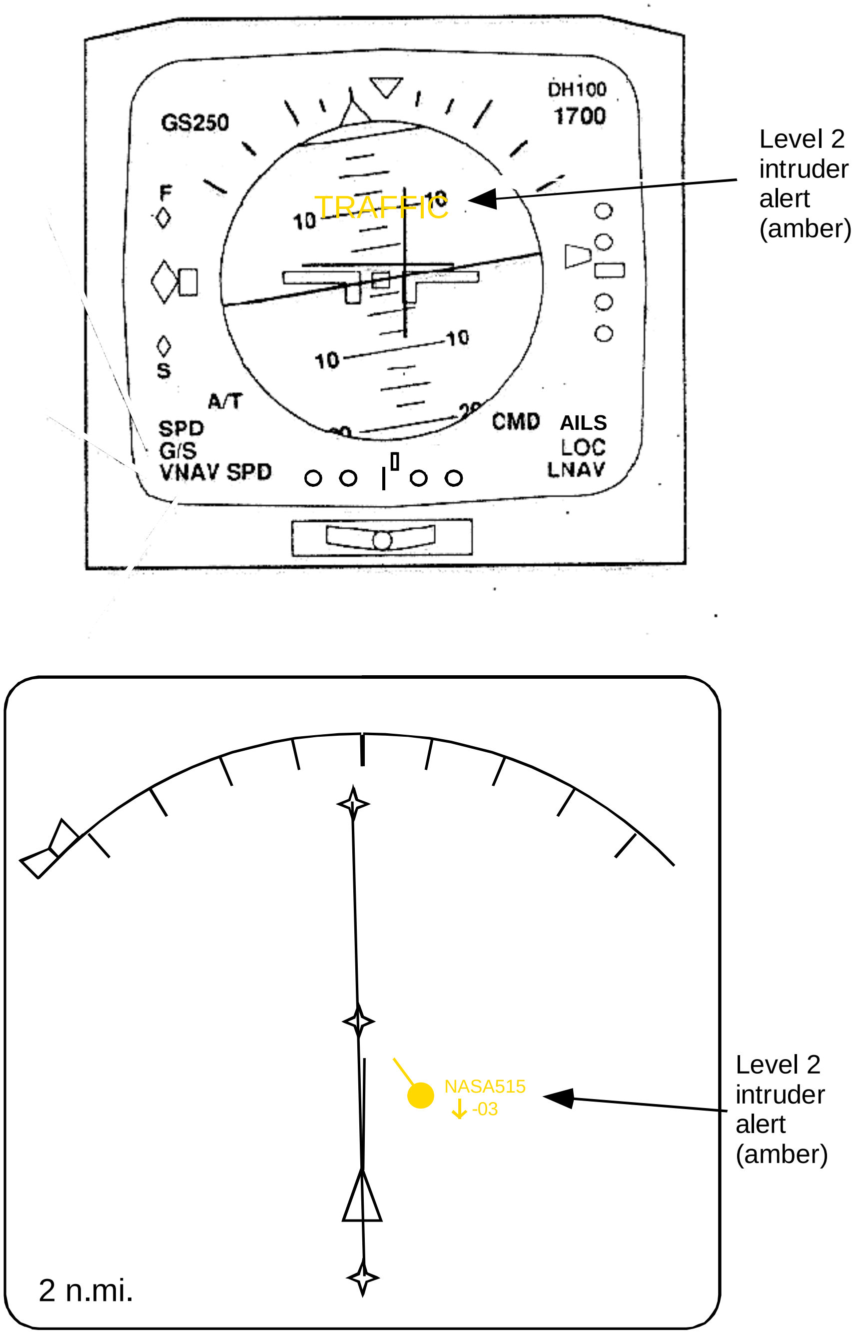


Figure 6. PFD and ND showing traffic threat caution alert.

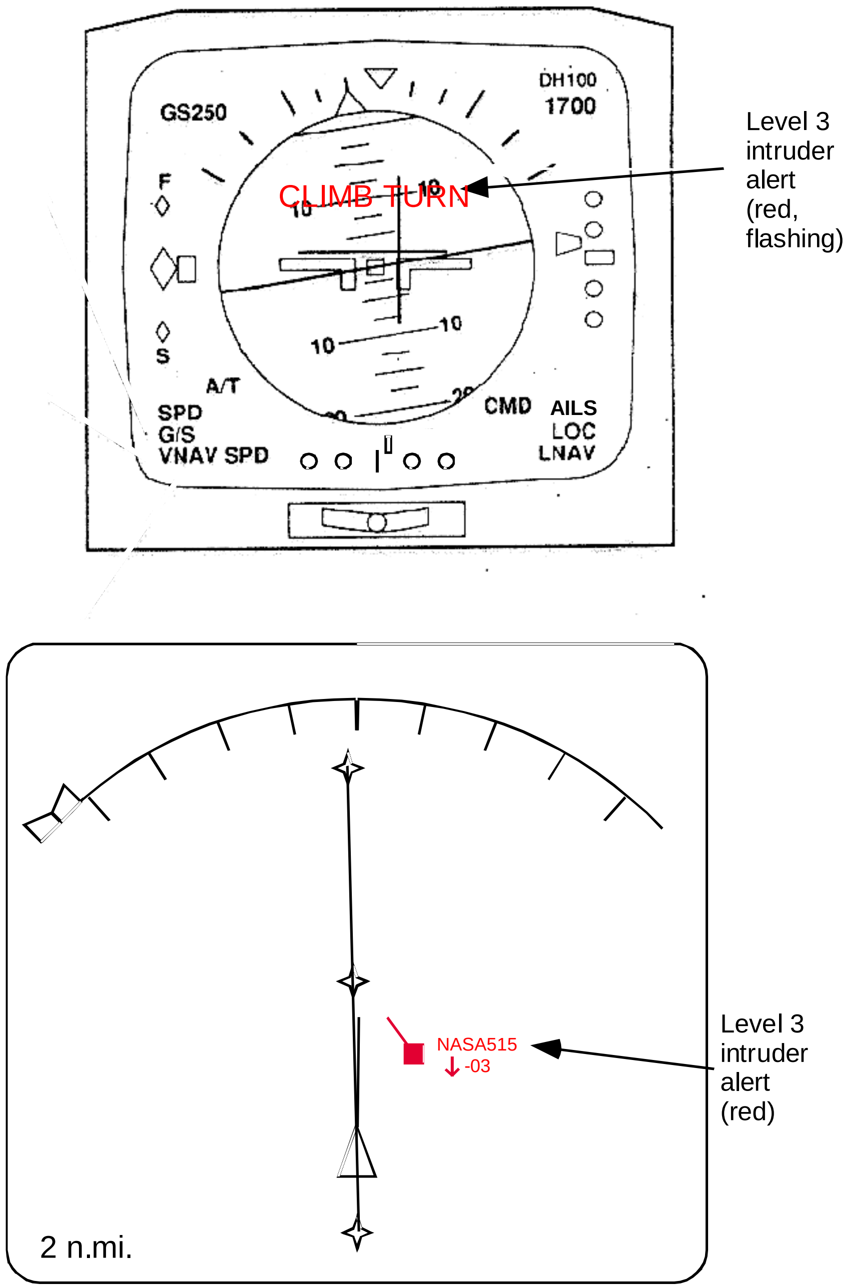


Figure 7. PFD and ND showing traffic warning alert

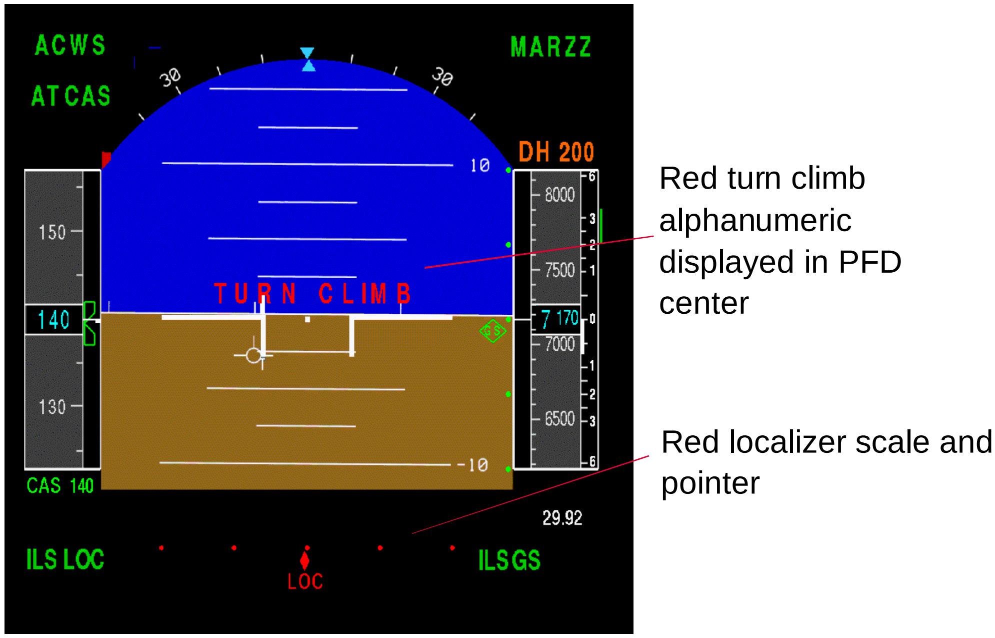


Figure 8a. Example of a warning traffic alert.

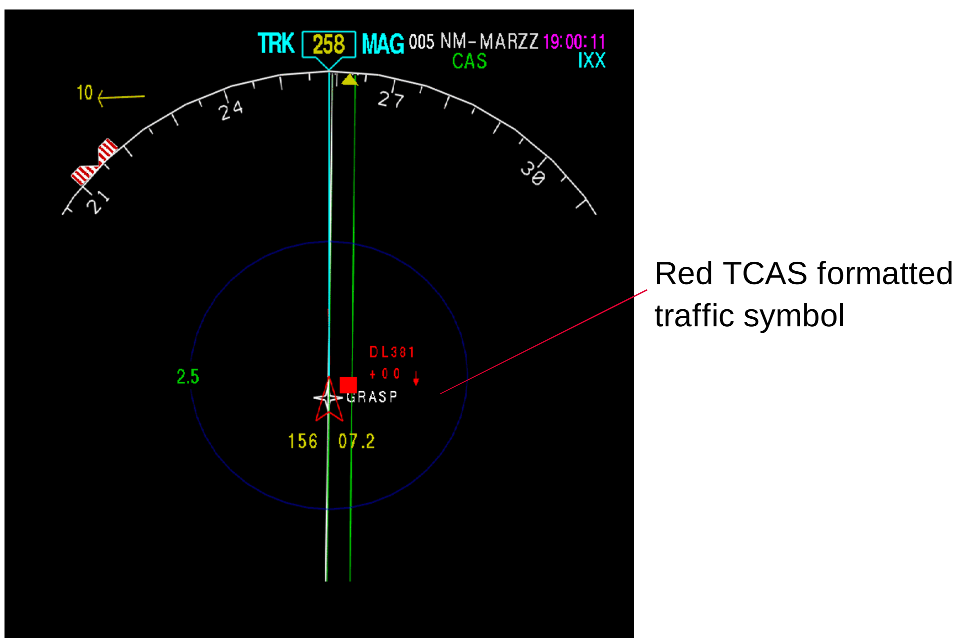


Figure 8b. Example of a warning traffic alert.

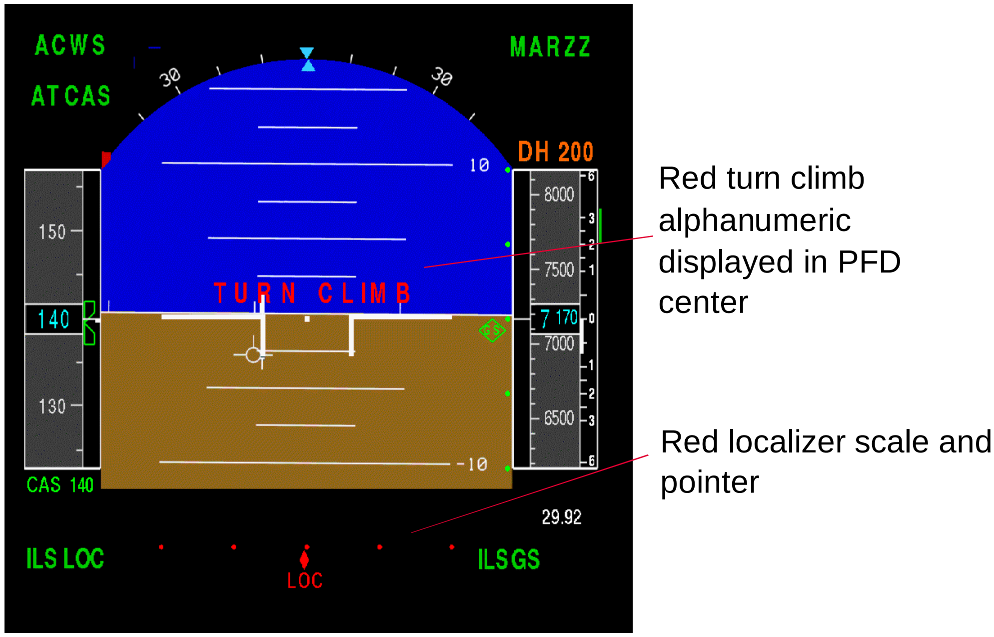


Figure 9a. Enhanced display format.

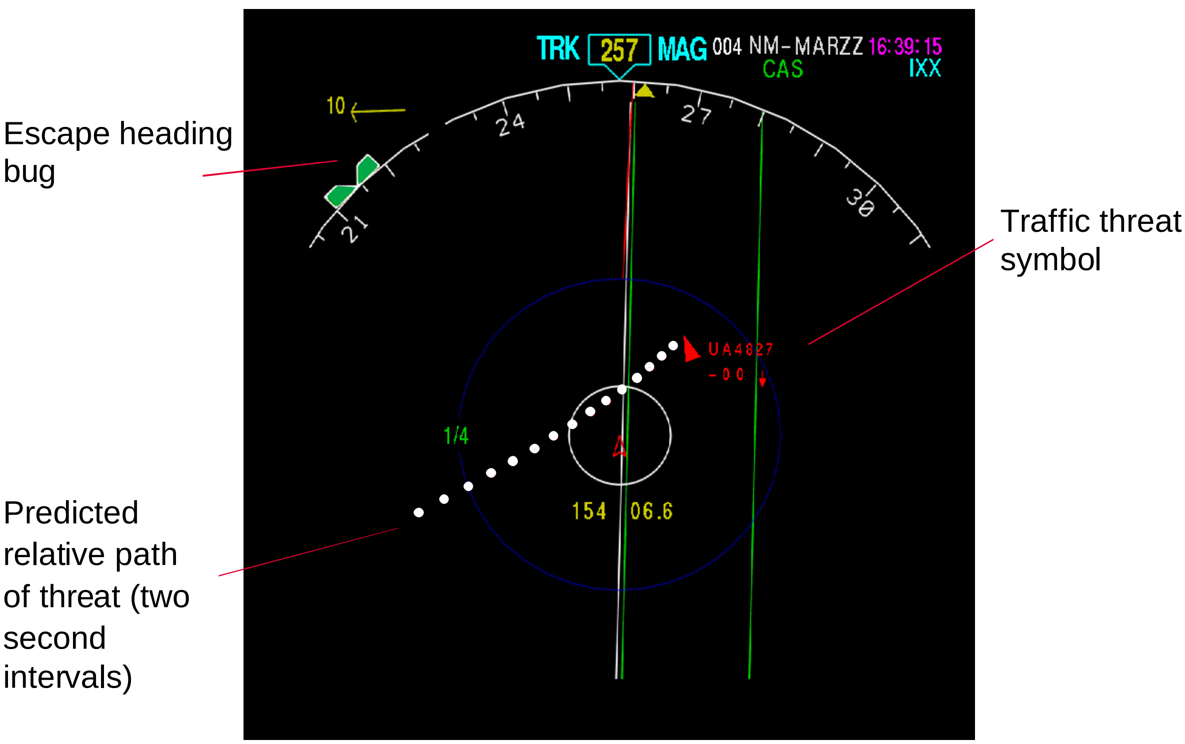
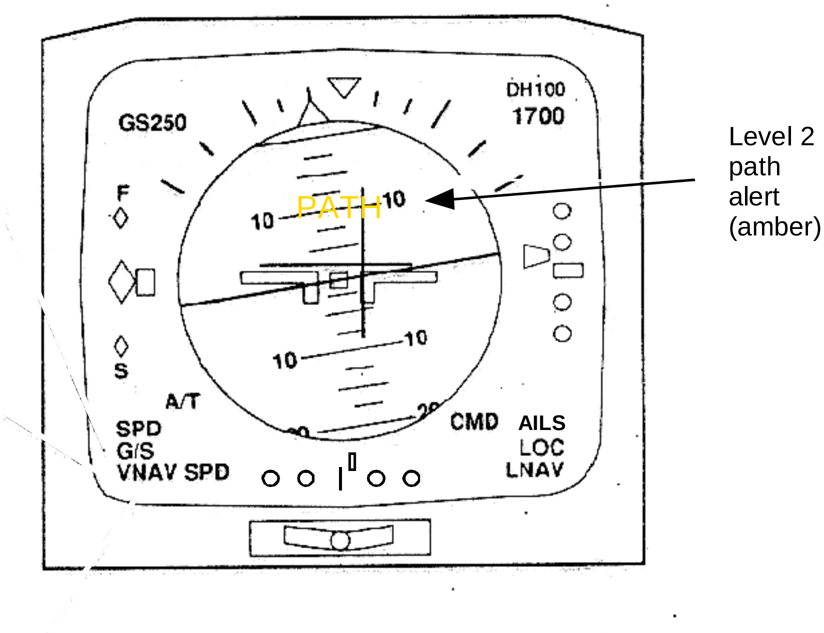


Figure 9b. Enhanced display format.



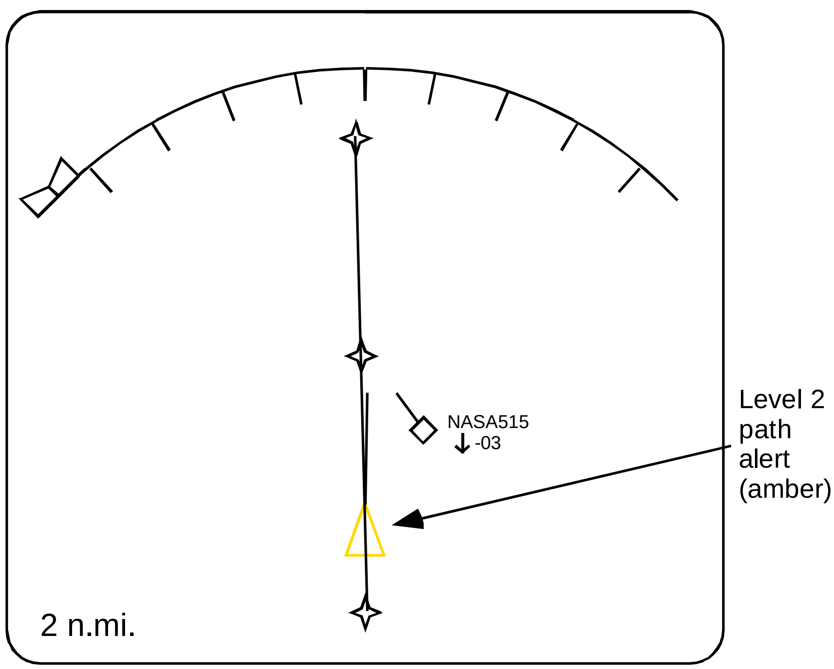


Figure 10. PFD and ND showing ownship off path caution alert

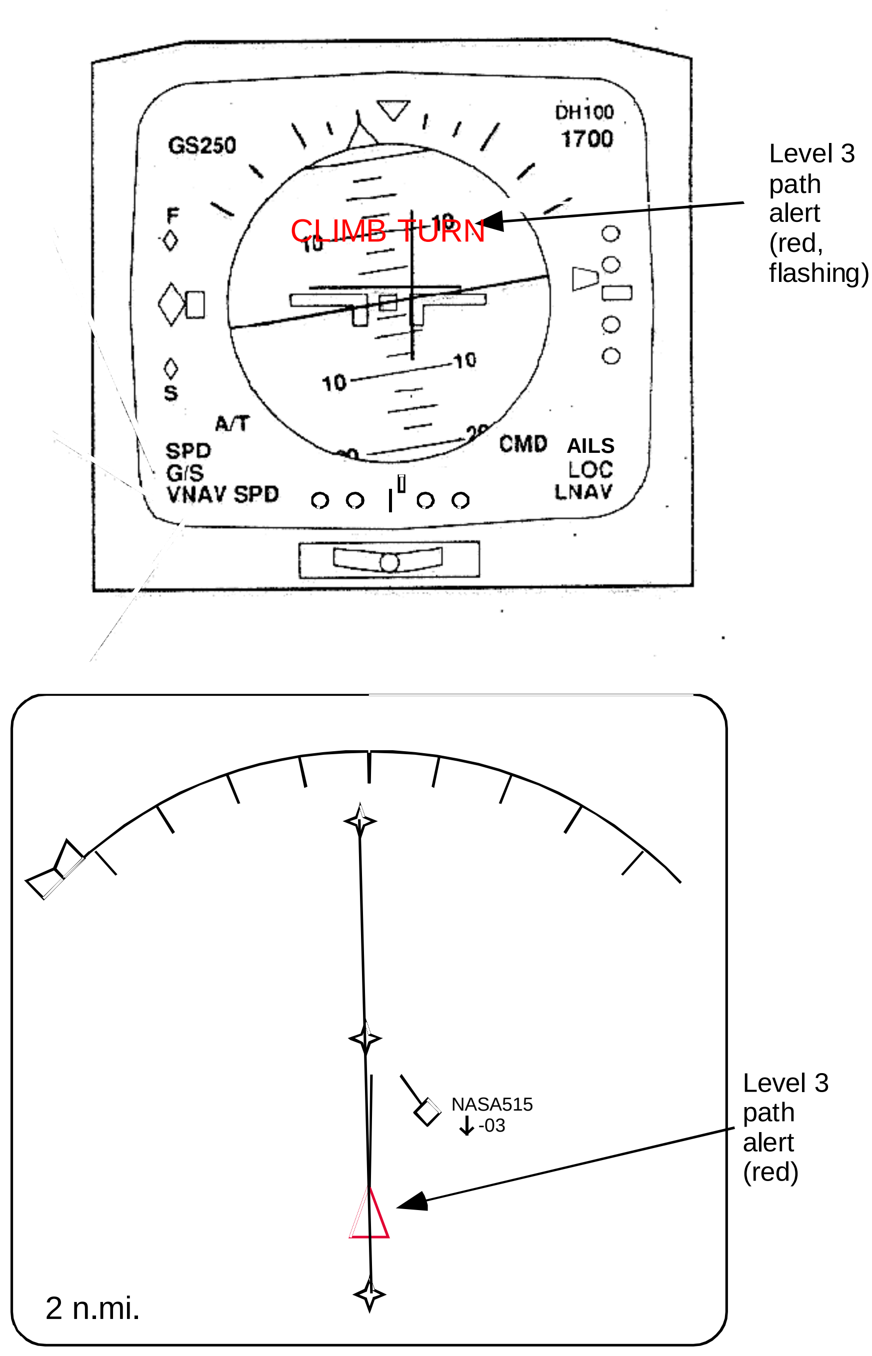


Figure 11. PFD and ND showing ownship off path warning alert

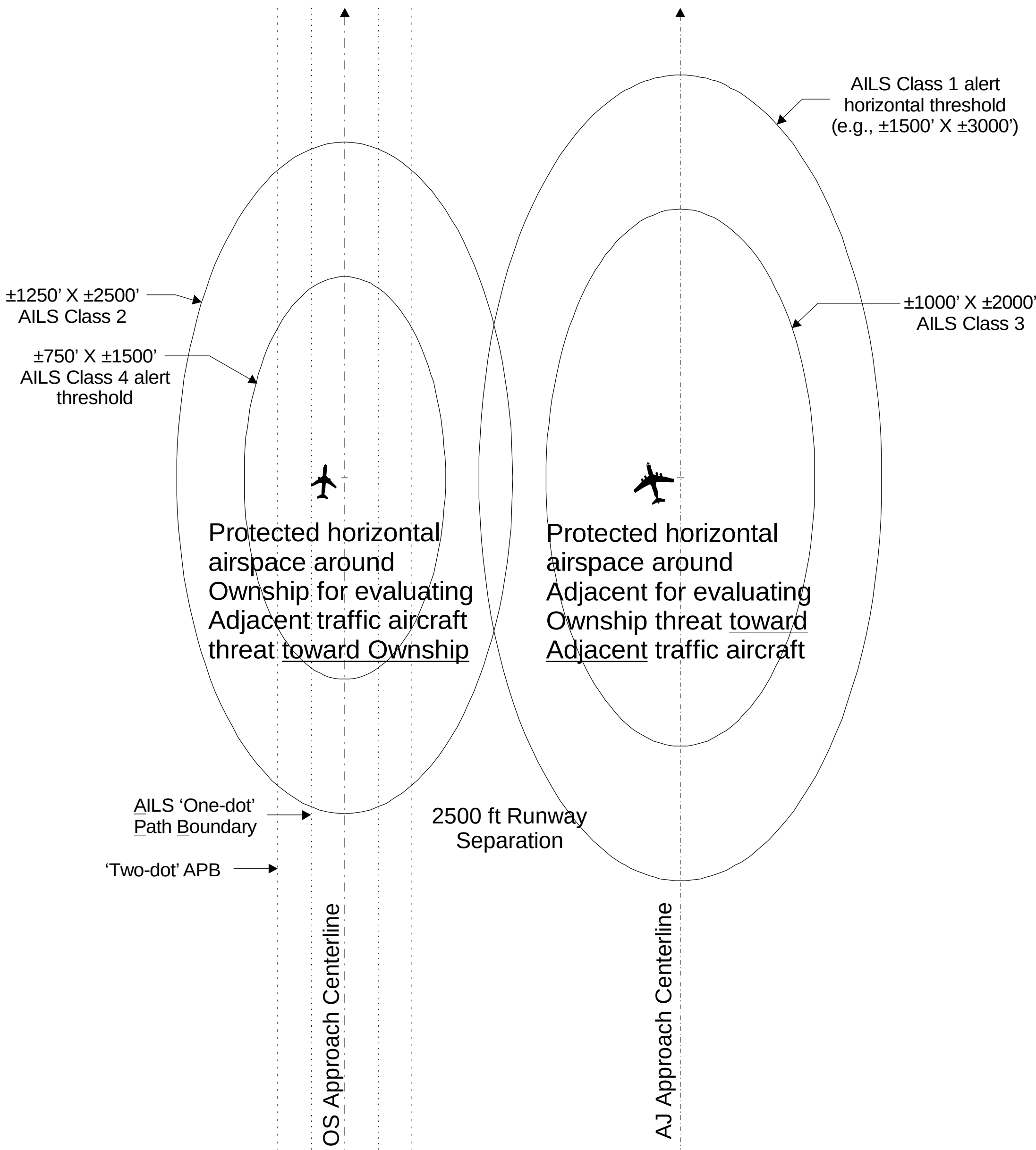


Figure 12. Example horizontal airspace thresholds for AILS alert classes

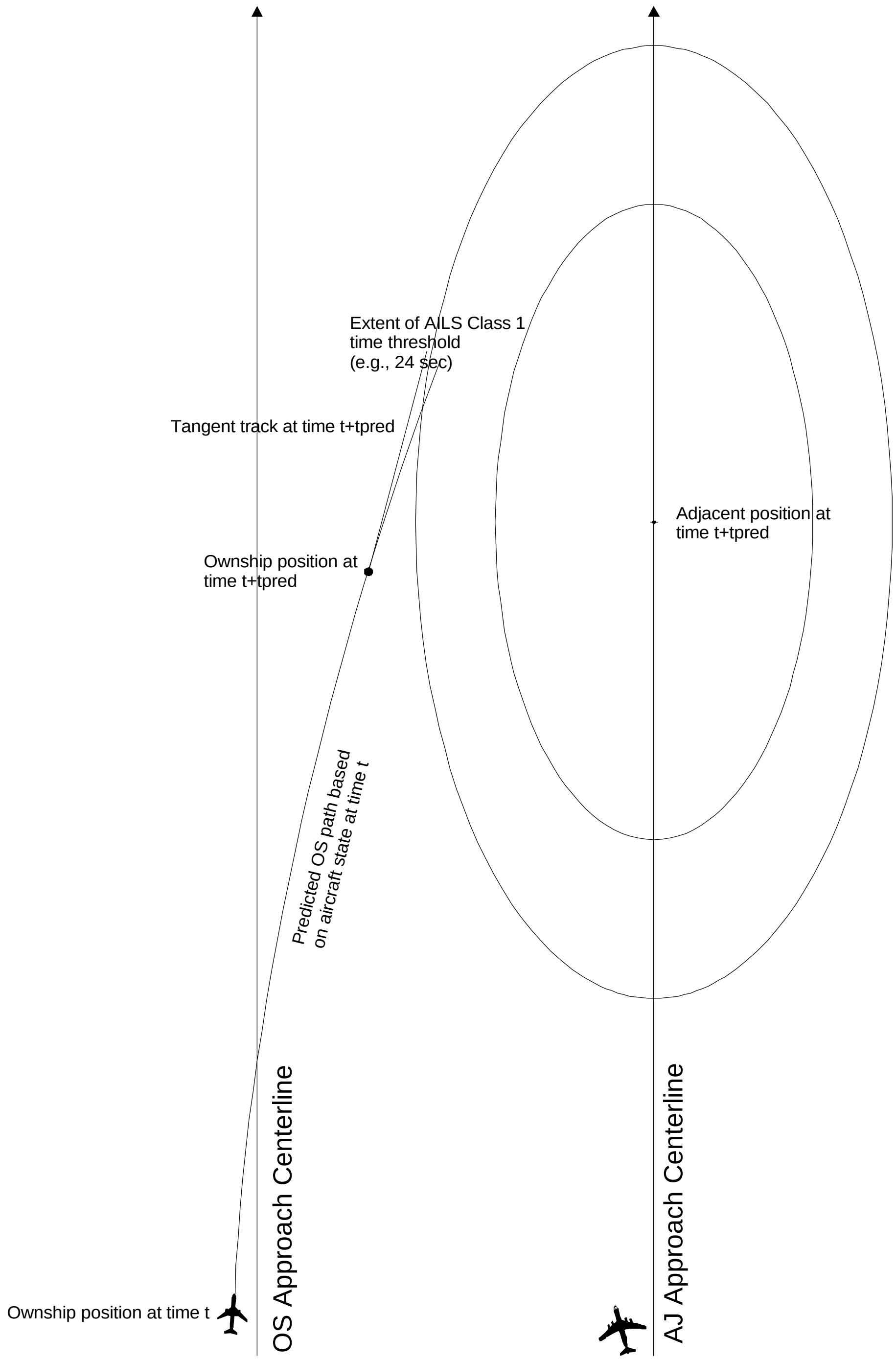


Figure 13. AILS Classes 1 & 3 Threat evaluations of ownship toward adjacent traffic

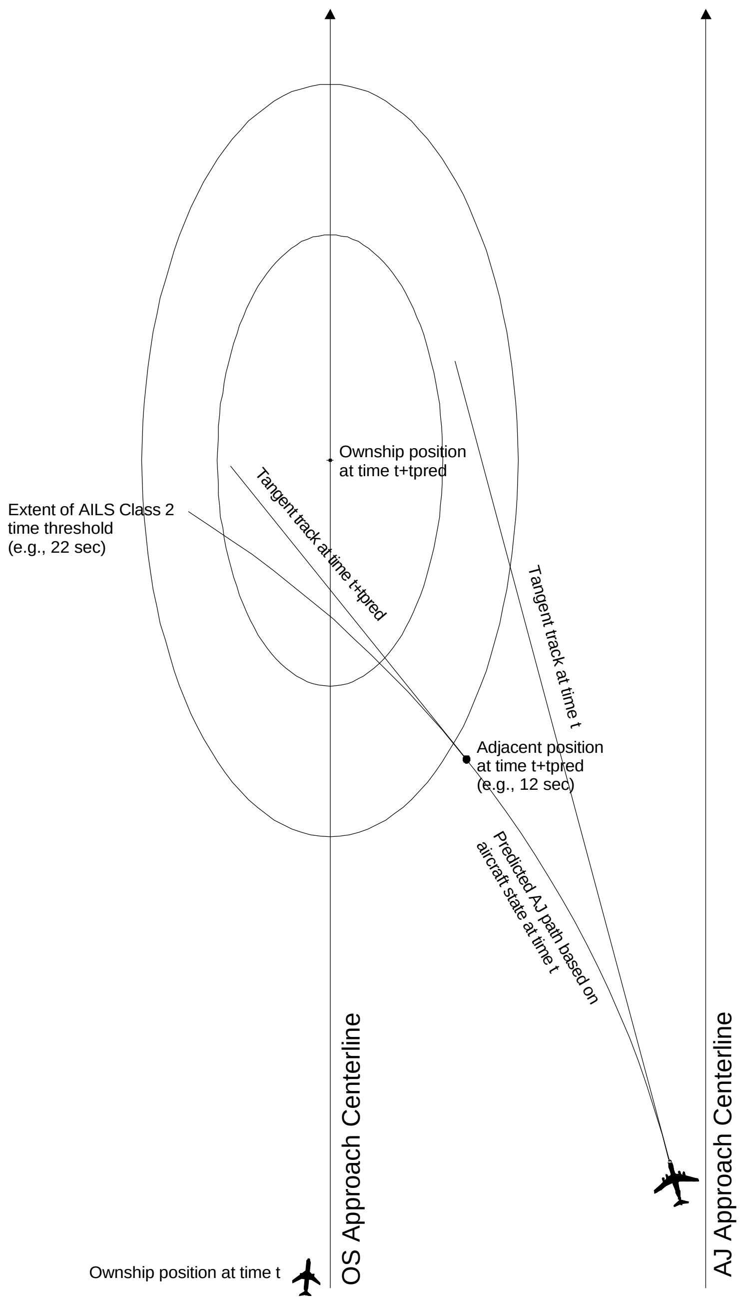


Figure 14. AILS Classes 2 & 4 Threat evaluations of adjacent traffic- aircraft toward ownship

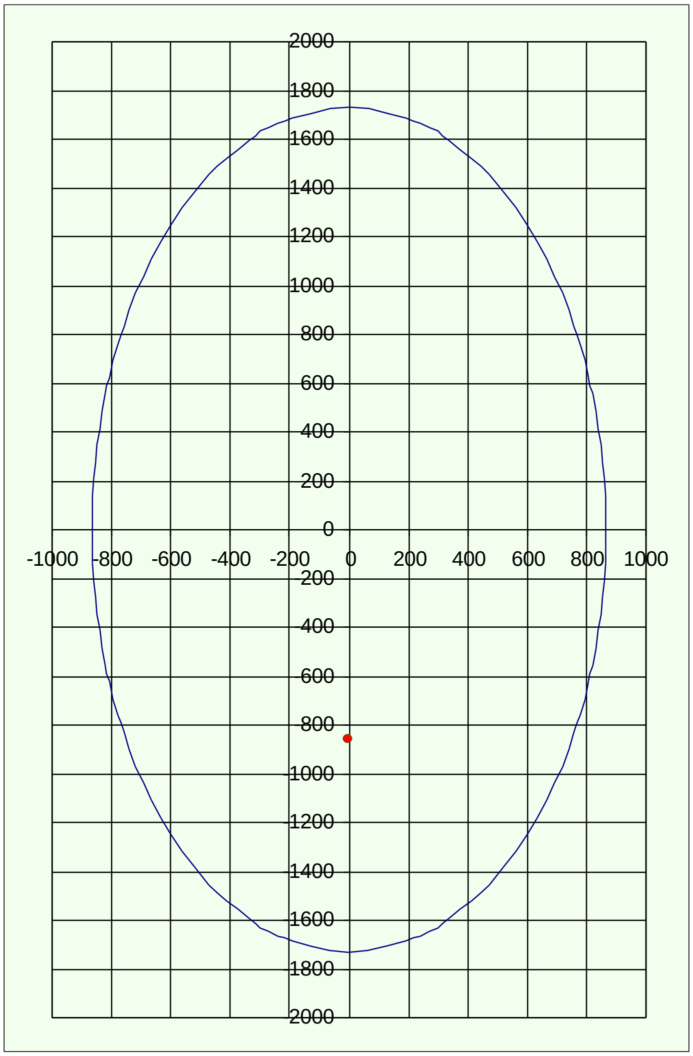


Figure 15. Illustration of elliptical protected airspace with along-track offset of aircraft position

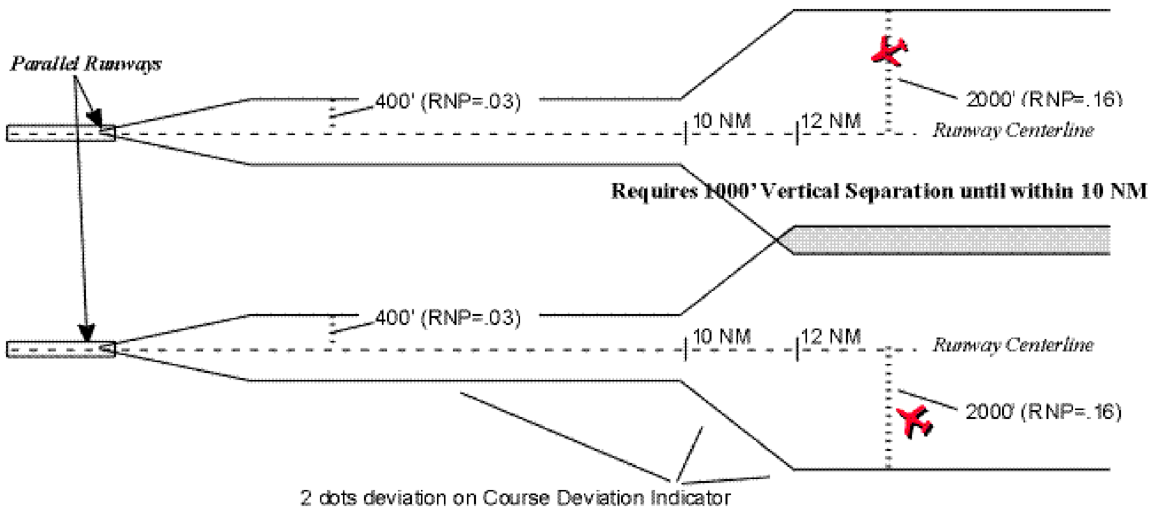


Figure 16. Approach Path Boundary (Rocketship plan view)